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U. S. S. *NEW YORK.*

DESCRIPTION AND OFFICIAL TRIALS.

BY HENDERSON B. GREGORY, ASSOCIATE.

The *New York* is a twin-screw battleship fitted with reciprocating engines, and designed for a speed of 21 knots, at 27,000 tons displacement, with the main engines developing 28,100 I.H.P. She is also known as Battleship No. 34, and was built at the Navy Yard, Brooklyn, N. Y., in compliance with an Act of Congress approved June 24, 1910, authorizing the construction of two first-class battleships, and which required that one be built at a navy yard. Her sister ship is the *Texas,* built by the Newport News Shipbuilding and Dry Dock Co., of Newport News, Va., whose principal features and trial data are described in the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. xxvi, No. 1.

PRINCIPAL HULL DIMENSIONS.

Length between perpendiculars, feet and inches	565–00
on L.W.L., feet and inches	565–00
over all, feet and inches	572–07¾
Breadth, extreme, on L.W.L., feet and inches	95–02⅝
molded, feet and inches	94–10⅛
Depth molded, main deck at side M.S., feet and inches	48–08⅛
Draught to L.W.L., feet and inches	28–05⅜
Displacement corresponding, tons	27,000
Ratio of length to beam	5.944
Displacement per inch at L.W.L., tons	92
Area of midship section, square feet	2,652
L.W.L. plane, square feet	38,560
wetted surface, square feet	65,700
Coefficient of fineness, block	0.61
midship section	0.99
L.W.L. plane	0.706

GENERAL DESCRIPTION OF HULL.

The hull is of steel throughout and of typical American design, with all turrets on the center line, two smoke pipes and the usual cage masts.

Masts.—There are two cage masts, with floors 113 feet 1½ inches high above the load water line, located at about frames Nos. 51½ and 76½; on which are located the spotter's tops and searchlight platforms—mounting two lights each; wireless, signal yards, etc.

Navigating Bridge.—The navigating bridge is just above the bridge deck and between the forward mast and conning tower. It extends athwartship to the side of the bridge deck.

Bridge Deck.—This is a small deck at the base of the forward mast, extending from frames Nos. 44½ to 54. It contains the chart house, and its forward end is taken up with the conning-tower foundations. It has portable extensions at either side, reaching to the vessel's sides.

Superstructure Deck.—This deck extends from the after side of turret No. 2 to frame No. 54, and contains a deck house in which are the captain's quarters.

Main Deck.—The main deck, on which is located the main battery, described elsewhere, is a weather deck throughout. Forward are located the windlass and a deck winch, and far aft a capstan. There are four deck houses, as follows: One forward, in which are the admiral's and chief of staff's quarters, the captain's and fleet officers' offices. In another, at the base of the forward smoke pipe, are the officers' galley, bakery, lamp room and lockers. A third, at the base of the after smoke pipe, contains the blacksmith shop, foundry, butcher shop and lockers. The fourth, below the after mast, is exclusively for the crew's galley. The two boat cranes are located amidship, port and starboard.

Gun Deck.—The gun deck extends from the stem to the stern. Forward of the diagonal armor are the wardroom officers' quarters. Within the casemate is part of the 5-inch battery, described elsewhere; printing office, armory, wardroom officers' bath and water closets, firemen's and mess attendants' wash rooms, drying rooms, coaling engines and bread rooms, general mess condiment and issuing room, lucky bag and post office. Aft of the diagonal armor is the crew's space, executive, ordnance and engineer officers' offices, paymaster's office, ship's stores, surgeon's examining room, dispensary, operating room and sick bay, laundry, master-at-arms and sergeant of marines' staterooms, general mess pantry, chief petty officers' and crew's washrooms and water closets, and electric capstan motor.

Half Deck.—This deck is forward of the forward diagonal armor, between the gun and protective decks. On it are located the junior and warrant officers' quarters, starboard and port respectively, and cleaning-gear room in the peak.

Protective and Berth Decks.—The protective deck extends at one level between frames Nos. 18 and 137, sloping off aft from frame No. 122. Forward of frame No. 18 it is dropped abruptly to the upper platform level and carried forward to the bow, the corresponding interval at former level being replaced by the berth deck, on which are located cofferdam, paint

and lamp rooms, commissary stores and the chain lockers. Above the sloping portion of the protective deck from frame No. 122, the berth deck, containing the chief petty officers' and crew's spaces, is carried aft at the protective-deck level. On the protective deck, from forward aft, are located forward ice-machine room, stores, blower rooms, crew's space, central station, band room, storage-battery charging station, coal bunkers, ammunition passages, boiler hatches, evaporator room, blower rooms, prison, clothing and small stores, crew's space, general workshop, ice machine and refrigerating rooms.

Upper Platform.—Next below the protective deck is the upper platform. Forward of the boiler rooms are electrical stores, distribution-board room, sub-central, radio room, intercommunication room, magazines, handling and shell rooms, windlass machinery, stores, pump room, chain lockers, paint and oil rooms and cofferdam. Extending through the boiler rooms, on the center line, is the wiring passage. The forced-draft blower rooms are located at this level in each fireroom, with coal bunkers outboard. Between the boiler and engine rooms is another distribution-board room; magazines, handling and shell rooms, with steam-pipe passages outboard. Abreast of the engine rooms are blower and store rooms. Abaft of the engine rooms are magazines, handling and shell rooms.

Lower Platform.—Like the former, the lower platform is interrupted by the machinery spaces. Forward are the forward trimming tanks, sails and awnings, hold, navigator's and ordnance stores, magazines, handling and shell rooms, torpedo room and forward dynamo room. Coal bunkers extend abreast of the boiler rooms, port and starboard, and the after dynamo room, together with magazines, handling and shell rooms are between the boiler and engine rooms. Again store rooms outboard of the engine rooms; and store rooms, steering-engine room, magazines, handling and shell rooms, pump and steering-gear rooms aft.

Hold.—In the hold, from forward aft, are located the for-

ward trimming tanks, fresh-water tanks, stores, forward dynamo-condenser room, boiler rooms, with coal bunkers outboard, after dynamo-condenser room, provisions, engine rooms, with wiring passage between; engineer's and ordnance stores, and the after trimming tanks.

Double Bottoms.—The double bottoms extend from frames Nos. 9 to 122. That portion under the boiler rooms, frames Nos. 61 to 73, forms the reserve feed-water tanks. Fuel oil is carried in tanks under the machinery spaces, frames Nos. 78 to 99. All other double bottoms are dry.

Capacities of Double-Bottom Compartments.

Com'p't.	Fresh water, tons.	Salt water, tons.	Com'p't.	Fresh water, tons.	Salt water, tons.
A–92	56.16	57.78	B–89	65.36	67.22
A–93	53.52	55.03	B–90	65.36	67.22
A–94	68.22	70.19	B–91	65.23	67.14
A–95	68.22	70.19	B–98	65.31	67.19
A–96	101.91	104.83	B–99	65.31	67.19
A–97	92.86	95.50	C–98	61.11	62.86
A–98	63.83	65.56	C–99	61.11	62.86
A–99	97.11	99.89	D–97	88.08	90.61
B–86	51.36	52.83	D–98	89.47	92.03
B–87	51.41	52.89	D–99	107.16	110.25
B–88	65.36	67.22			

COMPLEMENT.

The ship's complement will be approximately as follows:

Flag Officer	1
Chief of Staff	1
Commanding Officer	1
Wardroom Officers	30
Junior Officers	18
Warrant Officers	12
Crew (including 72 marines)	1,006
Total	1,069

BATTERY.

There are ten 14-inch guns in the main battery, arranged in pairs, in five turrets on the main deck along the center line of the vessel. Turrets Nos. 1 and 2 are forward, the latter being placed at sufficiently high elevation to permit ahead fire over the top of the former. Turret No. 3 is between the after mast and the engine hatches, and Nos. 4 and 5 are grouped abaft the engine hatches, the former elevated for astern fire over the latter.

The turrets are electrically operated, each containing the following electric apparatus:

No.	Character of Apparatus (Diehl Motors).	H.P. each.
2	Training motors	25
2	Upper ammunition hoists	40
2	Lower ammunition hoists	10
2	Elevating motors	15
2	Rammers	10

A secondary battery, of twenty-one 5-inch rapid-fire guns for torpedo defense, is also provided. Nineteen of these guns are distributed along the gun deck as follows: Divided port and starboard—four in the officers' quarters forward, ten in the casements and four in the crew's space aft, with one at the extreme stern on the center line. The two remaining guns are mounted on the bridge deck, port and starboard.

There are twenty-five electric-chain ammunition hoists for the secondary battery, each driven by a 3-horsepower Diehl motor.

The following smaller guns are also provided:

4 3-pdr. guns for saluting;
2 1-pdr. guns for boats;
2 3-inch field pieces;
2 0.30-caliber machine guns.

There are also four 5-m. by 21-inch submerged torpedo tubes forward. For charging the torpedoes, two Mark XIV,

Ingersol-Rand, electric-driven air compressors are provided. Each has a capacity of 30 cubic feet of air per minute, at 2,500 pounds pressure per square inch. The driving motors are 52 horsepower each. The plant is provided with two accumulators of 25 cubic feet capacity each.

SMALL BOATS CARRIED.

The following small boats comprise the ship's regular allowance and are carried on the main deck and in skid-deck beams at the superstructure-deck level abeam of the smoke pipes:

2 50-foot steamers;
1 40-foot steamer;
2 50-foot motor sailing launches;
2 40-foot motor sailing launches;
1 31-foot racing cutter;
2 30-foot whale boats;
2 20-foot dinghies;
2 14-foot punts.

There is also a stowage position for a flag officer's barge, which, in case the ship is a division flagship, would be a 40-foot motor barge.

When used as the flagship of the commander-in-chief the following boats are taken on board, replacing selected boats of the regular equipment:

1 50-foot motor barge for commander-in-chief;
1 35-foot motor boat for chief-of-staff.

Two electrically-operated boat cranes are provided for handling the boats, except the whale boats, which are hung in davits aft. Each crane has two operating gears—one for turning and the other for hoisting. The operating gears are driven by Diehl motors of 40 and 50 horsepower, respectively.

ANCHOR WINDLASS.

The anchor engine is located on the upper platform, frames Nos. 18 to 24. The engine is of the horizontal, double-cylinder, reversible type, built by the Hyde Windlass Co., of Bath, Maine. The cylinders are 16 inches diameter each by 16 inches stroke.

The windlass is driven by a worm gearing direct from a worm on the engine crank shaft. Attached to the worm gearing are two vertical shafts, each fitted on its upper end, at the main deck, with a wildcat, and so arranged that the wildcats can be operated together or independently of each other.

DECK WINCH.

An electrically-operated deck winch is located on the main deck, frames Nos. 22–24, center line. It is compound geared and has a lifting capacity of 16,000 pounds at 50 feet per minute, or 4,000 pounds at 250 feet per minute. The winch was made by the American Engineering Co., and is operated by a 35-horsepower Diehl motor.

COALING ENGINES AND GEAR.

There are two steam-driven coaling engines made by the Lidgerwood Mfg. Co. They are located amidship on the gun deck, frames Nos. 64 to 66. The engines are of the vertical, double-cylinder type, with cylinders 10 inches diameter by 10 inches stroke.

Each engine, through miter gears, drives an athwartship shaft, which in turn drives, port and starboard, fore-and-aft shafts; to which are geared eight gypsy heads each, which can be thrown in or out of gear at will by friction clutches. The athwartship shafts are cross-connected so that either engine can operate all gypsy heads if necessary. The capacity of the gear is 2,400 pounds on each gypsy head, at 200 feet per minute.

CAPSTAN.

Located at frames Nos. 128–129, center line, on the main deck, is an electric capstan, made by the American Engineering Co. It is compound geared, of same capacity as the deck winch and operated by a similar motor, located below on the gun deck.

STEERING ENGINE AND GEAR.

The steering-engine room is on the starboard side of the center line, just abaft of the engine rooms, access being from the starboard engine room. The engine, of the American Engineering Co.'s vertical, double-cylinder type, has cylinders 21 inches in diameter by 16 inches stroke.

From the steering engine a shaft is led aft to the tiller room, where is located the main steering gear, consisting of a right-and-left-hand screw, on which are two driving nuts direct connected by side rods to the rudder-stock crosshead. The screw is operated through gearing by the shaft, or emergency hand-steering gear, either of which may be disconnected when not in use.

In addition to the steam-steering engine, an electric gear is installed, driven by a 150-horsepower Diehl motor. It is located in the steering room and operates the steering gear through the engine shaft, suitable clutches being provided for throwing the engine and the motor in or out of gear.

The steering engine is controlled by telemotor, fitted in duplicate, from the steering platform, conning tower and central station. It may also be direct controlled by a handwheel in the steering room aft and one at the engine.

The control of the electric gear is from the same stations, steering-engine room excepted, as the steam gear.

The usual emergency hand gear is located in the steering room. It consists of four large hand-steering wheels mounted on a common shaft, which is connected through a train of gears and suitable cutout clutches, with the steering gear.

LAUNDRY.

A well equipped laundry, with capacity to wash for about 100 men, is located on the gun deck, frames Nos. 106 to 114, port side.

The laundry machinery is driven by a 6-horsepower Diehl electric motor, through suitable shafting and belting, and comprises the following apparatus:

1 32-inch × 54-inch double-geared, split-head, metal washer;
2 Wash tubs;
1 Soap tank (90 gallons);
1 Starch kettle (10 gallons);
1 20-inch Hogan extractor;
1 16-inch flatwork ironer;
1 Steam-heated bosom press;
1 30-inch steam-heated shoe, reverse body ironer;
1 Ironing table;
1 Drying room (conveyor type).

GALLEYS AND BAKERY.

The galleys and bakery are located in deck houses on the main deck, and, except for the customary steam kettles and coffee urns, are electric throughout; no coal ranges nor bake ovens being used. The officers' galley contains a five-section electric range, and that for the crew one of ten sections. The ranges were supplied by the General Electric Co.

Located in the crew's galley are the following electrically operated machines:

No.	Character of Machine.	H.P. of Motor.
1	Potato peeler	1
1	Meat chopper	¾
1	Cake mixer	½
1	Ice cream freezer	2

The bakery is equipped with two electric bake ovens and one dough mixer driven by a 2-horsepower motor.

An electrically-driven dish-washing machine, with ¾-horse-power motor, is provided for the general mess pantry.

DRAINAGE SYSTEM.

Main Drain.—The main drain, 15½ inches inside diameter, runs from the forward fireroom, in a single pipe, port side, to the forward bulkhead of the engine room, where it branches into two full-size pipes—one continuing aft through the port engine room, and the other athwartship, thence aft through the starboard engine room, both connecting to flanges provided on the main circulating-pump suction pipes.

There is a 15½-inch stop-check valve in the system in each engine and boiler compartment, for draining same, operated at place and from the protective deck. There is also a stop-lift-check valve at each connection to the circulating-pump suction pipes, so interlocked with the main injection valves that the latter must be closed before the former can be opened, as a safeguard against flooding the main drain from the sea.

As auxiliary connections to the main drain proper, there are two 5½-inch suction branches, via the secondary drain, to the engine-room fire and bilge pumps. These branches are each fitted with a Macomb strainer and a stop valve at the main.

Secondary Drain.—The secondary drain extends in single line, forward. Where it joins the fireroom system, there is a Macomb strainer and stop valve at junction. It is 4½ inches in diameter, with full-size suction branch from the drain tank forward, and 3-inch branches from the double bottoms and forward trimming tanks.

In the firerooms the main is 5½ inches in diameter, with branches to double bottoms and fireroom bilge wells, 3 inches and 5½ inches in diameter, respectively. Each fireroom fire and bilge pump has a 5-inch suction connection from the main, and a discharge to the sea of same diameter.

Each engine room is provided with a complete secondary drainage system. The main is 5½ inches in diameter, with

two full-size suction connections from the bilge wells. The two engine-room lines have a 5½-inch cross-connection, from which are taken 4½ and 3-inch connections for drainage system aft and the port shaft alley, respectively; the starboard shaft-alley drain being taken off the 4½-inch branch leading aft. The fire and bilge pumps in each engine room have a 7-inch suction from the main, dividing into the two 5-inch connections—one to each pump. The combined overboard discharge is 7 inches in diameter.

In addition to the former, there is a shaft bilge pump located in each shaft alley, with 4½-inch independent suctions from the after engine-room bilge and shaft alley, and overboard discharge of same size.

The after system is a single pipe 4½ inches diameter, with 3-inch branches, to the double bottoms and after trimming tanks. It is fitted with Macomb strainer and stop valve where it joins the engine-room system.

All suction connections from bilge wells in machinery spaces are fitted with Macomb strainers and stop-check valves operated at place only. The double-bottom suctions are fitted with stop-lift-check in way of machinery spaces, and stop-check valves elsewhere; the former being operated at place only, and the latter at place and from the protective deck.

There are two 2½-inch suction connections from the secondary drain—one in the forward fireroom, and the other in the port engine room, for hand pumps.

Chain-Locker Drains.—A 3-inch drain is led from the bottom of the chain locker to the drain tank forward, with stop valve at the tank. A 2-inch deck drain, from the windlass machinery space is also led into this pipe.

Torpedo-Tube Drains.—There is a 4½-inch drain pipe from each torpedo tube, combining into a common pipe of same diameter, fitted with stop valve and led to the drain tank forward.

Turret and Deck Drains.—2-inch deck drains are installed as required, each fitted with a valve on deck. Those forward

unite into a common main of 3 and 4½ inches diameter, with stop valve at end, discharging into the forward fireroom bilge. Amidship they form a common 3½-inch pipe, with stop valve at end, discharging into the port engine-room bilge. Aft the combined line is 3, 4 and 4½ inches diameter, discharging through stop valve into the port engine-room bilge.

TRIMMING TANKS.

There are four trimming tanks—two forward and two aft, of the following capacities:

Com'p't	Fresh water, tons.	Salt water, tons.	Com'p't	Fresh water, tons.	Salt water, tons.
A–1	90.66	93.25	D–12	191.72	197.20
A–2	117.84	121.21	D–13	48.50	49.89

The tanks are flooded from the sea by a 6-inch sea chest, forward and aft, and are pumped out through the secondary drain.

FIRE MAIN.

The fire main is supplied by eight fire and bilge pumps, located in the engine and firerooms. The two distiller circulating pumps can also be used on the fire main in emergencies.

The main is entirely below the protective deck, and extends throughout the machinery spaces and forward to frame No. 42, in two 6-inch lines, port and starboard. It is cross-connected at frames Nos. 42, 89 and 104, and supplied by two 6-inch risers from the engine-room fire and bilge pumps, and four 5-inch risers from the fireroom fire and bilge pumps, with cutout valves at the main.

Forward of frame No. 42 the main extends in single line to frame No. 18, in size 6 and 4 inches diameter.

Aft of the engine rooms a single line, 6, 5 and 4 inches in diameter, leads astern to frame No. 125, where it joins the independent sanitary system for the crew's water closets and

washroom aft. There is a stop valve where it joins the latter.

On the protective deck at frames Nos. 41 and 104, starboard, there are bypasses to the sanitary system. The bypasses are 6 inches in diameter and fitted with locked valves.

At frame No. 77, protective deck, amidship, there are two 4½-inch emergency connections for supplying circulating water to the distillers, which are also used for supplying the fire main by the distiller circulating pumps.

There are 6-inch flooding connections to all coal bunkers, branches to magazines flooding and sprinkling, and risers as required, leading to fire plugs on the decks above, distributed as follows:

Lower platform	1	Gun deck	25
Upper platform	14	Main deck	15
Protective deck	11	Superstructure deck	2
Berth deck	1		—
Half deck	3	Total	72

SANITARY AND FLUSHING SYSTEM.

The flushing main is 6 inches in diameter, and is supplied by six 5-inch risers from the fire and bilge pumps, and two 6-inch bypasses, one forward and one aft, from the fire main.

It is carried in the protective-deck space, close under the gun-deck beams, and extends from frames Nos. 41 to 104, at which point it reduces in size to 4 inches and continues aft to frame No. 121, where it rises to the gun deck and leads aft to frame No. 129, joining the crew's independent flushing main, with stop valve at junction.

Branches, as required, are led to the chief petty officers' washroom and water closets, sick-bay, bath, laundry, general mess pantry, galleys, bakery, firemen's washrooms, junior, warrant and wardroom officers' lavatories and water closets, etc.

Aft there is an independent system for the exclusive use of the crew's washroom and water closets. This system is supplied by two motor-driven, direct-connected, centrifugal pumps*, of about 500 gallons per minute capacity each. The main is 5 inches in diameter, with the necessary branches to the plumbing fixtures.

FRESH-WATER SYSTEM.

The following fresh-water tanks are provided:

Compartment or tank.	Location.	Between frames.	Gallons.
A-6	Hold-port	18–21	9,760
A-7	" starbd.	18–21	9,760
A-8	" port	21–24	11,860
A-9	" starbd.	21–24	11,860
Main gravity tank	Top of deck house	59–62	2,000
Aux. gravity tank	Top of chart house	52–53	150
Firemen's supply tank	Top of deck house, port	64–65	450
Do.	Do. stbd.	61–62	450
Battle dressing-station supply tank	Protective deck, stbd	48–49	125
Do.	Do.	114–115	125

The hold tanks have two 2½-inch filling connections from the ship's sides forward, and also a 3-inch connection from the distiller main. From these tanks water is pumped, through the fresh-water main, to the main gravity tank, by means of two triple-plunger electric-driven pumps.* There is also a 1½-inch discharge connection from these pumps for filling the auxiliary gravity tank, which supplies water, through an independent system, to the officers' quarters above the main deck.

The main gravity tank supplies the entire fresh-water system, except as noted in preceding paragraph, including the various supply tanks. In case the gravity tank is out of order, all parts of the ship supplied by it may be supplied by the pumps direct through the main. The main is 3 inches in diameter, and has a 3-inch branch to the main gravity tank and

*See Table II.

other branches as required to the supply tanks, officers' baths, pantries, galleys, bakery, sick bay, crew's washroom, scuttlebutts, etc.

MAGAZINE FLOODING AND SPRINKLING.

There are three flooding systems for the three groups of magazines—forward, amidship and aft. Each system floods the magazines of its group on the lower platform, while magazines on the upper platform are flooded or sprinkled from the fire main.

Each system is provided with a 9-inch sea chest, from which pipes are led, with branches to the various magazines as required. Adjacent to the sea connections are stop valves operated at place and from the protective deck.

A sprinkling system is fitted in all magazines. It is supplied by the fire main, and in the magazines consists of 2½-inch brass pipe perforated on the under side, so that each powder tank can be sprinkled. There are cutout valves for each magazine operated at place and from the protective deck.

MAGAZINE COOLING SYSTEM.

Provision is made for cooling, by brine circulation, all magazines, except those containing saluting powder and small-arms ammunition. For this purpose 1-inch galvanized-iron pipe coils are fitted overhead in the magazines that require cooling, through which the previously cooled brine is circulated. Suitable drip pans are fitted under all coils to catch the condensation.

REFRIGERATING PLANT.

The refrigerating apparatus is of the CO_2 type, as manufactured by the Kroeschell Bros. Ice Machinery Co. It consists of five vertical and one horizontal electric-driven compressors, 2½-inch bore by 8-inch stroke, direct connected to electric motors—15-horsepower General Electric units designed to run at 100 revolutions per minute. Each compressor

is capable of producing the cooling effect of 6 tons of ice per day.

The installation is divided into two independent plants—one forward, on the protective deck, frames Nos. 18 to 21 port, for the exclusive use of the forward magazines. It consists of one horizontal compressor set, together with its water circulating and brine pumps,* brine tank, condenser and the necessary piping and fittings. The other, or main plant, is located in the refrigerating-machinery room on the protective deck, port of the engine hatches. There are five vertical compressor sets in this group, arranged so that any or all machines can be used on the refrigerating rooms, ice-making tank, scuttle butts or magazines, including those forward. There is one large condenser for this group of compressors, together with two electric-driven centrifugal water circulating pumps,* three electric-driven centrifugal brine circulating pumps,* a brine cooler, ice-making tank, and all the necessary piping and fittings. The refrigerating rooms, ice-making tank, scuttle butts and magazines are brine cooled; the brine, previously cooled in the brine coolers, being forced through the system by the brine circulating pumps and returned to the coolers, from which the cycle is repeated. The brine coolers are cooled by the CO_2 gas, which is taken from the condenser liquid receivers, circulated through the brine coolers and returned to the compressors.

There are four refrigerating rooms, on the protective deck, just abaft of the main refrigerating machinery room. All the rooms are fitted with 1-inch galvanized iron-pipe coils, through which the cooling agent is circulated. The crew's compartment serves as vestibule for the butter and meat rooms, and the officers' cooling room has no vestibule, its door opening direct to the passage. A hatch is provided through the gun deck for charging the meat room. The rooms are cork insulated in the usual manner.

*See Table II.

RESERVE-FEED TANKS AND FILLING CONNECTIONS.

The following double bottom compartments are fitted up as reserve-feed tanks:

Comp't.	Fresh water, tons.	Comp't.	Fresh water, tons.
B–92	53.78	B–95	53.69
B–93	53.78	B–96	53.78
B–94	53.78	B–97	53.69

A 3½-inch filling pipe is led across the ship on the gun deck, frame No. 64, both outboard ends of which are carried through the main deck and fitted with two 2½-hose valves each. Amidship it has a 3-inch by-pass filling connection to the fresh-water main, fitted with locked valve, and a 4-inch branch led down into fireroom No. 3, where it joins the filling and suction manifold, through which the various compartments are filled.

FUEL-OIL TANKS AND FILLING CONNECTIONS.

The double bottoms under the machinery spaces, frames Nos. 78 to 99, are arranged for carrying fuel oil as follows:

Compt.	Gallons.	Compt.	Gallons.
C–90	20,942	C–94	17,000
C–91	20,942	C–95	17,000
C–92	17,575	C–96	15,233
C–93	17,563	C–97	14,947

For filling the fuel-oil compartments, two 6-inch pipes are led across the ship under the main deck, with hose valves at the ship's side, frames Nos. 100–101 starboard and 103–104 port; and on the main deck at frames Nos. 85 starboard and 89 port. These pipes are combined into an 8-inch pipe, which leads down the starboard engine hatch to the manifolds in the engine rooms, individual oil compartments being filled through the manifolds and suction pipes from the tanks.

An 8-inch overflow pipe is fitted to the filling pipe in engine hatch, discharging overboard.

COAL–BUNKER CAPACITIES.

Comp't.	Tons.	Comp't.	Tons.
B–5–P	91.5	B–102	81.7
B–5–S	90.6	B–103	81.9
B–7–P	145.8	B–104	84.4
B–7–S	145.8	B–105	84.4
B–9–P	163.3	B–106	80.5
B–9–S	163.3	B–107	80.6
B–11–P	151.0	B–108	78.9
B–11–S	151.0	B–109	78.9
B–13–P	135.1	B–110	97.3
B–13–S	135.1	B–111	97.3
B–15–P	134.3	B–112	96.6
B–15–S	134.3	B–113	96.6
B–17–P	105.7		
B–17–S	105.7	Total	2,892.5

VENTILATING SYSTEM.

Artificial ventilation is provided where necessary for all quarters, living spaces, passages, storerooms, magazines, engine rooms, dynamo rooms, evaporator room, etc. There are forty-nine ventilating fans and motors, each on its own circuit. In general air is supplied on the plenum system to the different compartments requiring ventilation. The toilet spaces and engine rooms are also provided with the exhaust system. The ventilating fans were made by the B. F. Sturtevant Co., Boston, Mass., and the motors by the Diehl Mfg. Co., except those for the engine-room exhaust fans, sets Nos. 45 to 48 inclusive, which were built by the General Electric Co.

Table I contains the particulars of the ventilating fans and motors.

Heater boxes are fitted in the ventilating ducts to all quarters below the main deck, crew's space, etc., for heating the incoming air in cold weather; no other heating apparatus being provided for these spaces.

TABLE I—VENTILATING FANS—U.S.S. NEW YORK.

SET No.	LOCATION			MOTOR			FAN	
	DECK	P OR S	FRAMES	OPEN OR ENCLOSED	HP	R.P.M.	SUPPLY OR EXHAUST	CAPACITY CU. FT. OF AIR PER MIN.
1	TURRET I	S	26-27	O	4.8	790	S	5000
2	" I	P	" "	O	"	"	S	"
3	" II	S	36-37	O	"	"	S	"
4	" II	P	" "	O	"	"	S	"
5	" III	S	88-89	O	"	"	S	"
6	" III	P	" "	O	"	"	S	"
7	" IV	S	109-110	O	"	"	S	"
8	" IV	P	" "	O	"	"	S	"
9	" V	S	119-120	O	"	"	S	"
10	" V	P	" "	O	"	"	S	"
11	GUN	C.L.	100-101	E	2.19	1055	E	2500
12	"	P	113-114	E	0.88	1560	S	1000
13	"	P	124-125	O	2.19	1055	S	2500
14	HALF	C.L.	12-13	E	"	"	E	"
15	BERTH	C.L.	" "	E	0.88	1560	S	1000
16	"	S	18-19	O	2.19	1055	S	2500
17	"	S	30-31	O	7	590	S	8000
18	"	P	32-33	O	4.37	745	S	5000
19	"	S	" "	O	"	"	S	"
20	"	P	35-36	O	"	"	S	"
21	"	P	45-46	O	3.5	835	S	4000
22	"	P	46-47	O	"	"	S	"
23	"	S	" "	O	"	"	S	"
24	"	P	48-49	O	8.75	500	S	10000
25	"	S	" "	O	"	"	S	"
26	"	P	76-78	O	7	590	S	8000
27	"	S	" "	O	7	"	S	"
28	"	P	81-82	E	0.88	1560	E	1000
29	"	S	" "	E	"	"	E	"
30	"	P	83-84	O	2.19	1055	S	2500
31	"	S	" "	O	"	"	S	"
32	"	S	" "	O	3.5	835	S	4000
33	"	S	86-87	O	7	590	S	8000
34	"	P	92-93	O	7	"	S	"
35	"	S	" "	O	7	"	S	"
36	"	P	114	O	8.75	500	S	10000
37	"	S	"	O	7	590	S	8000
38	UPPER PLAT.	C.L.	42-43	E	0.25	2200	E	425
39	" "	C.L.	137-138	O	3.5	835	E	4000
40	" "	P	91-92	E	10.5	485	S	12000
41	" "	S	" "	E	"	"	S	"
42	" "	P	93-94	E	"	"	S	"
43	" "	S	" "	E	"	"	S	"
44	STR'G. FLAT	P	123-124	O	2.19	1055	S	2500
45	BERTH	S	94-95	O	8.5	485	E	12000
46	"	P	" "	O	"	"	E	"
47	"	S	95-96	O	"	"	E	"
48	"	P	" "	O	"	"	E	"
49	MAIN	S	48-49	E	0.26	2050	S	425

HEATING SYSTEM.

All staterooms and quarters below the main deck, crew's space, etc., are heated by the thermo-tank ventilating system; heater boxes provided with suitable steam coils being placed in

the air ducts for heating the air supplied to these compartments. The remaining portions of the vessel, *i.e.*, quarters on the main, superstructure and bridge decks, are heated by the customary pipe-coil steam radiators.

The heating system is divided into two main sections, one forward and one aft. The forward section is taken off the main steam cross-connection pipe in fireroom No. 2, starboard side, with stop and reducing valves adjacent to the steam line, and is subdivided into five independent circuits as follows:

Circuit No.	Description.	Working pressure. Pounds.
1	Crew's and officers' galleys and bakery.....	20
2	Bath, shower and lavatory-water heaters forward of frame No. 74; pantries and fresh-water tanks	20
3	Heater boxes (2), protective deck, frames 32–33 port and 34–35 starboard.....	50
4	Heater boxes (4), protective deck, frames 46–47 port, 45–46 starboard and 51–52 port and starboard	50
5	Radiators in quarters on main, superstructure and bridge decks, and fresh-water tanks on chart house	50

The after section is taken off the auxiliary steam loop in engine rooms, with stop and reducing valves at the line, and is subdivided into eight independent circuits as given below:

6	Heater boxes (2), gun deck, frames 92–93 port and starboard.....	50
7	Heater boxes (2), protective deck, frames 91–92 port and starboard.....	50
8	Heater box in steering room.....	50
9	Heater boxes (3), gun deck, frames 124–125 center line, protective deck, frames 112–113 port and starboard.....	50
10	Heater boxes (2), gun deck, frames 112–113 port and starboard.....	50

11 Heater box for hospital space, gun deck, frames 111–112, starboard, and radiator in operating room 50
12 Laundry and general mess pantry..... 20
13 Bath, shower and lavatory heaters aft of frame No. 74..... 20

The drains, from circuits Nos. 3, 4 and 5, are collected into a manifold and led to a common trap in fireroom No. 2. Drains from circuit No. 1 and pantries and fresh-water tank coils, circuit No. 2, are led to a trap located in the same fireroom. The drains from water heaters, circuits Nos. 2 and 13, are led direct to the auxiliary exhaust line. Circuits Nos. 6, 7, 8, 9, 10 and 11 are led to a drain manifold in the port engine room, which connects to a trap in the same engine room. There is also an independent trap in the port engine room for the drain from circuit No. 12. All traps discharge into the low-pressure trap discharge main.

The following is a list of the heater boxes in the ventilating ducts:

No.	Location.			Heating surface, sq. ft. each.	Steam from circuit No.	On ventilating system No.
	Deck.	Frames.	P. or S.			
2	Gun.	92–93	P. and S.	186.4	6	34 and 35
1	"	111–112	S.	58.3	11	36
2	"	112–113	P. and S.	129.7	10	36
1	"	124–125	C. L.	174.3	9	13
1	Protective.	32–33	P.	355.1	3	18
1	"	34–35	S.	355.1	3	19
1	"	46–47	P.	161.1	4	24
1	"	45–46	S.	124.8	4	25
2	"	51–52	P. and S.	259.1	4	24 and 25
2	"	91–92	P. and S.	115.6	7	34 and 35
1	"	112–113	P.	69.4	9	36
1	"	112–113	S.	82.8	9	36
1	Steering-engine room.	125	P.	80.3	8	.....

MAIN ENGINES.

There are two main engines designed to develop collectively 28,100 indicated horsepower, when making 125 revolutions

per minute. They are placed abreast in two separate watertight compartments, as shown in Plate I.

The engines are of the vertical, inverted-cylinder, direct-acting, four-cylinder, triple-expansion type, turning outboard when going ahead. The order of the cylinders, beginning forward, is forward low-pressure, high-pressure, intermediate-pressure and after low-pressure. All crank angles are 90 degrees, the sequence of cranks being high-pressure, intermediate-pressure, forward low-pressure, and after low-pressure.

Bedplates.—The bedplates are of cast steel, in three sections each, bolted together and supported on keelson plates. Proper seatings and facings are provided for the main bearings, columns, etc.

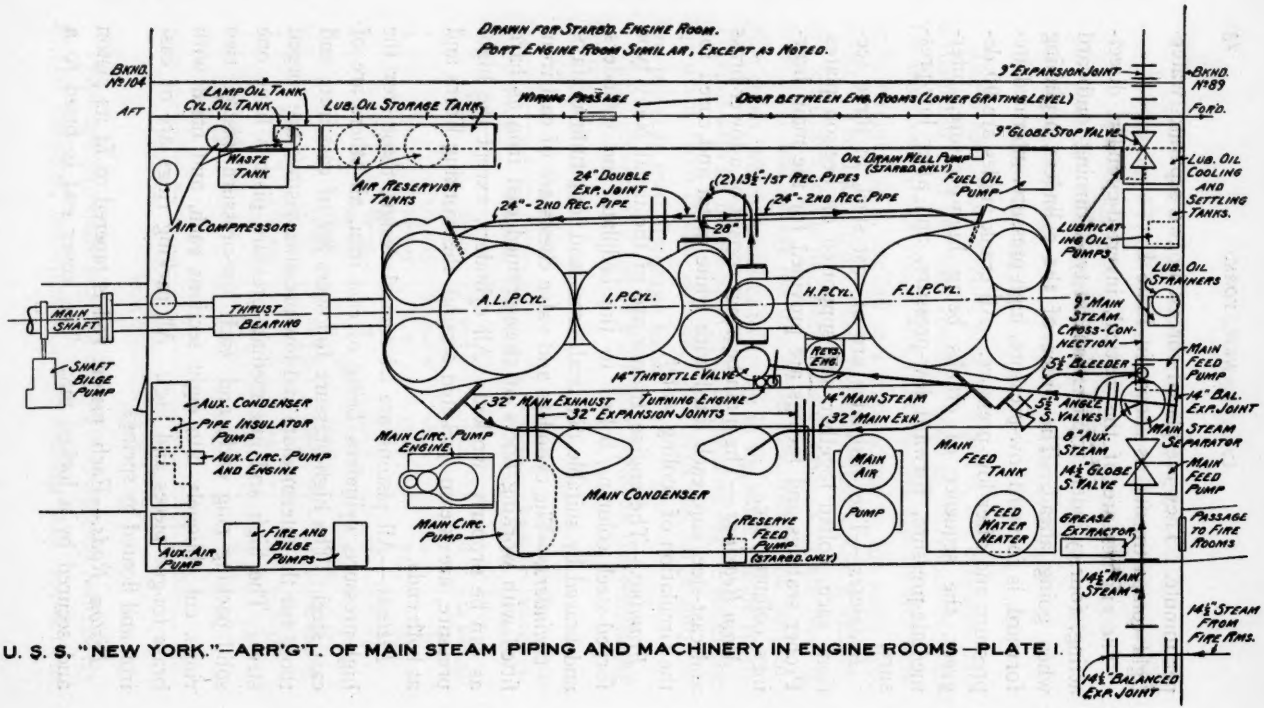
Main Bearings.—The main bearings consist of a lower brass and cast-steel cap, each lined with white metal and cored for the circulation of cooling water.

Framing.—The engine frames are of the usual Navy type forged-steel columns, bolted to the bedplate and cylinders, and braced by suitable diagonal, cross and longitudinal stays.

Cylinders.—The cylinders and valve chests are of cast iron, fitted with working liners of close-grained cast iron as hard as can be properly worked. All cylinders, except the high-pressure, are steam jacketed around the working liners and at both ends.

Pistons.—All pistons are of conical design, those for the high-pressure cylinders being of cast iron, all others are of cast steel. The high-pressure followers are of cast iron, and those for the intermediate and low-pressure pistons are forged steel. The high and intermediate-pressure pistons have one solid packing ring each, and each low-pressure piston two rings, cut obliquely into eight sections each, and fitted with brass tongue pieces and lugs. All packing rings are of cast iron and floated by springs.

Piston Rods.—Each piston rod is tapered to fit its piston and secured by a locked nut. The lower end is fitted to a



U. S. S. "NEW YORK."—ARR'G'T. OF MAIN STEAM PIPING AND MACHINERY IN ENGINE ROOMS—PLATE I.

forged-steel crosshead, to which is bolted a cast-steel slipper, white-metal lined. The piston rods are forged steel.

Crosshead Guides.—The go-ahead guides are of cast iron, hollowed for the circulation of cooling water. The backing guides are of cast steel and securely bolted to flanges on the go-ahead guides. The guides are supported by bolting to facings on the cylinders at the upper end, and to a cast-steel girder of "I" section at the lower end; the girder being secured to the inboard engine columns.

Connecting Rods.—The connecting rods are of forged steel, forked at the top to span the crosshead and carrying the crosshead brasses, and "T" headed at the bottom to receive the crank-pin brasses.

Valve Gear.—The engines are equipped with the Stephenson, double-bar link valve gear, fitted with Lovekin assistant cylinders. Piston valves are used throughout; there being one for each high-pressure and two for each intermediate and low-pressure cylinders.

Reversing Gear.—Each main engine is provided with a reversing engine of the vertical, direct-acting type, bolted to the high-pressure cylinder and connected through connecting rods to the reversing-shaft arms; the shaft in turn connecting to the main links by arms and suspension rods. Each reversing engine has a steam cylinder 17 inches in diameter by 22 inches stroke, and an 8½-inch oil-controlling cylinder of same stroke, for taking up shock and for hand operation, a small hand pump being provided for that purpose. The gear is controlled by a floating lever operated at the working platform.

Turning Gear.—The customary turning gear is fitted on each engine, consisting of a double engine, with cylinders 7 inches in diameter by 5 inches stroke. The engines drive, by worm gearing, a second worm, which may be made at will to mesh with a worm wheel fitted on the crank shaft. The turning engines are reversible.

Each turning-engine shaft is also fitted for turning by hand.

Lubricating Gear.—All working and moving parts of the

main engines, except the valve links and valve-stem guides, which are efficiently lubricated by combination sight and wick-feed oil-distributing boxes, located on the main cylinders, are lubricated by the forced-lubrication system, described elsewhere. The crosshead guides are provided with both gravity and forced lubrication.

Water Service.—Water service is provided for each main engine by a 4-inch pipe from the discharge pipe of the main circulating pump. This pipe has suitable branches to the various parts of the main engine, thrust and spring bearings; the discharge being returned to the suction side of the same pump.

Working Platform.—Owing to the fact that the forced-lubrication system requires the crank pits to be totally inclosed by a thin galvanized sheet-steel casing extending up nearly to the bottoms of the cylinders, the working platforms are on the first grating above the engine-room floor, there being a door through the center-line bulkhead, at this level, between the engine rooms.

Main Engine Data.

Working pressure at H.P. chest, pounds gage	265
Revolutions per minute, designed	125
Indicated horsepower, total designed	28,100
Diameter of H.P. cylinder, inches	39
I.P. cylinder, inches	63
L.P. cylinders (2) inches	83
Stroke, inches	48
Ratio, I.P. to H.P.	2.61
L.P. to H.P.	9.06
L.P. to I.P.	3.47
Total expansions	10.92

	Per cent. of volume.		Linear, inches.	
Cylinder clearances:	Top.	Bottom.	Top.	Bottom.
Starboard, H.P.	14.29	13.54	$\frac{7}{16}$	$\frac{9}{16}$
I.P.	12.18	14.88	$\frac{9}{16}$	$\frac{17}{64}$
F.L.P.	14.06	16.5	$\frac{9}{16}$	$\frac{9}{16}$
A.L.P.	13.43	16.1	$\frac{1}{2}$	$\frac{35}{64}$
Port, H.P.	14.29	13.54	$\frac{15}{32}$	$\frac{9}{16}$
I.P.	12.18	14.88	$\frac{31}{64}$	$\frac{19}{32}$
F.L.P.	14.06	16.5	$\frac{29}{64}$	$\frac{21}{32}$
A.L.P.	13.43	16.1	$\frac{15}{32}$	$\frac{21}{32}$

Valves and valve settings:	H.P.		I.P.		L.P. (each).	
Number and type of valves	1 piston.		2 piston		1 piston.	
Diameter of valves, inches	$22\frac{1}{16}$ top. 22 bottom.		$24\frac{1}{16}$ top. 24 bottom.		$34\frac{1}{8}$ top. $34\frac{1}{16}$ bottom.	
Travel of valves, inches	10		11		12	
Inside or outside steam	Inside		Outside.		Outside.	
	Top.	Bot.	Top.	Bot.	Top.	Bot.
Width of port, inches	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{1}{4}$
Steam opening, linear, inches	$3\frac{9}{16}$	$3\frac{5}{16}$	$3\frac{5}{16}$	$3\frac{7}{16}$	$2\frac{1}{16}$	3
Exhaust opening, linear, inches	Full port.		Full port.		Full port.	
Steam lap, inches	$1\frac{13}{16}$	$1\frac{11}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$3\frac{3}{16}$	3
Exhaust lap, inches	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{1}{2}$
Steam lead, linear, inches	$\frac{1}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	1	$1\frac{1}{16}$	$1\frac{1}{2}$
Cutoff, decimal of stroke	85.15	78.65	81.5	73.7	67.06	56.9
mean	81.9		77.6		61.98	

Piston rods, diameter, outside, inches	08¼
axial hole, inches	1½ H.P. and I.P., 4 L.P.
Connecting rods, diameter, crosshead end, inches	07½
crank end, inches	09¼
axial hole, inches	1½ H.P. and I.P., 4 L.P.
length between centers, inches	96
crank ratio	4
Diameter of throttle valve, inches	14
1st receiver pipes (2), inches	13½
2d receiver pipe, inches	24
main exhaust pipes (2), inches	32
live-steam pipes to receivers, inches	03

SHAFTING AND BEARINGS.

There are two lines of shafting, each consisting of a crank shaft in two sections, a thrust shaft, one piece of line shafting, a stern-tube shaft and a propeller shaft, all supported by suitable bearings.

Crank Shafts.—The crank shafts are solid-forged, hollow shafts, in two sections each; bolted together by disc couplings, and carried in seven main bearings. The forward section includes the H.P. and F.L.P. cranks, which are opposite, as are also the I.P. and A.L.P., on the after section. All crank angles are ninety degrees, the two sections being connected with the H.P. crank leading followed by the I.P. crank.

Thrust Shafts.—The thrust shafts are fitted to the usual thrust bearings of the adjustable horse-shoe type, with steady

bearings at each end for supporting the shafts. The shafts are hollow with thrust collars and coupling discs forged integral with the shafts.

Line Shafts.—These shafts are hollow forged, with disc couplings at either end, and each is carried by one steady bearing.

Stern-Tube Shafts.—The stern-tube shafts are covered with a composition casing within the stern tubes and at bearings. They are hollow forged, secured to the line shafts at inboard end by special disc couplings, and to the propeller shafts at outboard end by the usual sleeve couplings, the shafts being taper turned to suit. Each stern tube is provided with two lignum vitae lined bearings for supporting the shafts. There is also one spring bearing in each shaft alley supporting the overhanging ends of these shafts.

Propeller Shafts.—Each propeller shaft is carried by two lignum vitae lined bearings, fitted to the forward and after struts. The shafts are hollow forged, taper turned at both ends to suit the propeller hub and sleeve coupling, and composition bushed at the bearings.

Inboard Coupling.—The inboard coupling consists of a sleeve secured to the stern-tube shaft by four keys. Back of the sleeve is a collar made in halves and secured to the sleeve and to the coupling disc on the line shaft by fitted bolts.

Outboard Coupling.—The outboard coupling is of the solid-sleeve type, taper bored to fit the shafts, and secured to each shaft by two feather keys and one cross key.

Shaft Data.

Crank shafts, length, forward section, feet and inches	17–03¼
after section, feet and inches	19–04
diameter, inches	18¾
axial hole, forward section, inches	11½
after section, inches	10½
number of cranks	4
throw of cranks, inches	24
crank angles, degrees	90

Crank pins, length, inches	23
diameter, inches	19½
axial hole, forward section, inches	12
after section, inches	10
Thrust shafts, length, feet and inches	16–04¼
diameter, inches	17¾
at bearings, inches	18
axial hole, inches	11½
collars, number	14
thickness, inches	02
space between inches	04
outside diameter, inches	27½
inside diameter, inches	18
bearing surface, square inches	4,752.85
Line shafts, length, feet and inches	18–00
diameter, inches	18
axial hole, inches	11½
Stern-tube shafts, length, feet and inches	51–08⅝
diameter, inches	18½
axial hole, inches	11
Propeller shafts, length, feet and inches	55–09¾
diameter, inches	18½
axial hole, inches	11
Coupling discs, diameter, inches	33
thickness, inches	04
Inboard coupling, diameter of sleeve outside, inches	33
inside, inches	20½
length of sleeve, inches	12
thickness of collars, inches	4
Coupling bolts, number each coupling	8
diameter (taper)* at face of coupling, inches	03⅞
Outboard couplings, length of sleeve, inches	73⅞
diameter of sleeve, inches	24¼

Bearing Data.

Main bearings (white-metal lined):	
Number each engine	7
Diameter, inches	18¾
Length, inches	two of 15, three of 24 and two of 27¾
Thrust bearings (white-metal lined bearings and shoes):	
Steady bearings, number each	2
diameter, inches	18
length, inches	19

*Parallel bolts for inboard coupling.

Thrust shoes, number each	14
effective surface, square inches	3,046
Line-shaft bearings (white-metal lined):	
Number each engine	2
Diameter, inches	18
Length, inches	26
Stern-tube bearings (lignum vitae lined):	
Number each engine	2
Forward bearing, diameter, inches	20⅝
length, inches	48
After bearings, diameter, inches	20⅝
length, inches	65
Strut bearings (lignum vitae lined):	
Number each engine	2
Forward bearing, diameter, inches	20$\frac{11}{16}$
length, inches	38
After bearing, diameter, inches	20¾
length, inches	63

PROPELLERS.

There are two twin-screw, three-bladed, propellers of the adjustable-pitch, detached-blade type. They are of manganese-bronze and the blades are secured to the hubs by seven 4¾ tap bolts each. The blades are machined true to pitch and the hubs have a taper fit on the shafts, and are secured by a key and nut.

Propeller Data.

Diameter of propeller, feet and inches	18–08¼
hub, feet and inches	4–06
Pitch as set, feet and inches	19–11$\frac{9}{16}$
adjustable from, feet and inches	18–11¼ to 21–02$\frac{7}{32}$
Ratio of diameter to pitch	0.9361
Area, projected, square feet	83.43
helicoidal, square feet	98.5
disc, square feet	274.27
Ratio, projected to disc area	0.309
helicoidal to disc area	0.361
Heighth of lower tip of blade above keel, inches	7½
Immersion of upper tip of blade, inches	117⅜

MAIN CONDENSING APPARATUS.

Main Condensers.—There is one main condenser of cylindrical form for each main engine, with tubes rolled into the tube sheets at one end and gland packed at the other. The principal dimensions follow:

Inside diameter, feet and inches	7–09
Thickness of shell (steel), inch	00 7/16
Length betwen tube sheets, feet and inches	15–00
Thickness of tube sheets, inches	1 3/8
Tubes, number	5,340
diameter, outside, inch	00 5/8
thickness, inch	00.065
Cooling surface, square feet	13,104
Diameter of main exhaust nozzles (2), inches	32
auxiliary exhaust nozzle, inches	08
air-pump suction, inches	12
circulating-water inlet and outlet, inches	23

**Main Air Pumps.*—Each main condenser is provided with a Blake, vertical, twin, bucket, single-acting air pump, with steam and water cylinders 14 and 35 inches diameter, respectively, by a common stroke of 21 inches. The suction nozzle is 12 inches and the discharge nozzle 10 inches in diameter.

**Main Circulating Pumps and Engines.*—There is one double-inlet centrifugal circulating pump for each main condenser, driven by a vertical compound engine. The engine is provided with a self-contained forced-lubrication system, with branch connection from the main engine system. The principal dimensions of the pump and engine are as follows:

Capacity of pump, gallons per minute	21,000
Diameter of suction nozzle (2), inches	17
discharge nozzle, inches	23
impeller, inches	42
H.P. cylinder, inches	10
L.P. cylinder, inches	20
Stroke, inches	10
Revolutions per minute	235

*See Table II.

Feed and Filter Tank.—A feed and filter tank of 3,920 gallons capacity is located in each engine room, outboard side and forward of the main condenser. The filter chamber is in the top of the tank and has a capacity of about 814 gallons. The filter has an inner bottom of loose perforated plates and is divided into three compartments, in which is placed the filtering material, by vertical division plates. These partitions are so arranged that the water in passing through the filter will flow under and over in succession, thus assuring the filtering material being always submerged.

Each tank is provided with the following connections:

1 10-inch main air-pump discharge;
1 8-inch cross-connection;
2 5½-inch main feed-pump suctions;
1 4-inch auxiliary air-pump discharge;
1 2½-inch reserve-feed pump discharge (starbd. only);
1 8-inch overflow;
3- and 2-inch vapor pipes (combined into one 3-inch pipe).

ENGINE-ROOM AUXILIARIES.

Auxiliary Condensers.—In each engine room there is an auxiliary condenser connected through the auxiliary exhaust pipe to all the auxiliary machinery. The tubes are rolled into the tube sheets at one end and packed at the other.

They are of the following principal dimensions:

Inside diameter, feet and inches	2–00
Thickness of shell (steel), inch	00$\frac{5}{16}$
Length between tube sheets, feet and inches	6–06¼
Thickness of tube sheets, inch	01
Tubes, number	333
diameter, outside, inch	00⅝
thickness, inch	00.065
Cooling surface, square feet	355.24
Diameter of auxiliary exhaust nozzle, inches	06
air-pump suction, inches	06
circulating-water inlet and outlet, inches	05

**Auxiliary Air Pumps.*—A Blake, vertical, double-acting, single, featherweight, air pump is provided for each auxiliary condenser, with steam and water cylinders of 7½ and 14 inches diameter, respectively, by a common stroke of 12 inches. The suction nozzle is 6 and the discharge nozzle 4 inches in diameter.

**Auxiliary Circulating Pumps.*—Each auxiliary condenser is equipped with a double-inlet centrifugal circulating pump, driven by a vertical, single engine, fitted with a self-contained system of forced lubrication. The general dimensions of the pump and engine follow:

Diameter of suction nozzle, inches	05
discharge nozzle, inches	05
impeller, inches	28
steam cylinder, inches	05
Stroke, inches	04
Revolutions per minute	400

Feed-Water Heater.—Two Reilly multicoil feed-water heaters are installed—one in each engine room. They have 319.8 square feet of heating surface each, and are connected to the main feed lines only. The heating agent is the exhaust steam, a back pressure being kept in the auxiliary exhaust line for this purpose by means of a spring-relief valve at each connection to the main and auxiliary condensers, opening toward the condenser.

**Main Feed Pumps.*—Two Blake, vertical, double-acting, single, main feed pumps are installed on the forward bulkhead of each engine room. The pumps have independent suctions from the main feed tanks in same engine room and discharge to the boilers through the feed-water heaters or bypassing same.

**Reserve Feed Pump.*—A small Blake, vertical, double-acting, single, reserve feed pump is fitted in the starboard engine room, for use in port to pump makeup feed water from the reserve feed tanks into the main feed tanks.

*See Table II.

**Main Fire and Bilge Pumps.*—Located aft, on the outboard bulkhead, in each engine room, are two Blake, vertical, double-acting, single, fire and bilge pumps. They are arranged to draw water from the drainage system and the sea, and discharge to the fire main, sanitary system and overboard.

**Pipe Insulator Circulating Pumps.*—In each engine room there is a Blake, vertical, double-acting, single pump, for circulating sea water around the main steam-pipe flanges at bulkheads near magazines, to prevent the transmission of heat through the ship's structure to the magazines.

FORCED-LUBRICATION SYSTEM.

All working and moving parts of the main engines, except the valve links and valve-stem guides, are fitted with forced lubrication.

The installation in each engine room comprises three pumps,* two 500-gallon oil-settling and cooling tanks, together with the necessary piping and fittings. The settling and cooling tanks are provided with steam coils and cooling coils, the cooling agent being sea water, supplied from the pipe insulator circulating system. Each engine-room system is complete and independent, a cross connection being provided, however, for emergencies. The crank pits are of oiltight construction, fitted with an oil-drain well at the forward end, and so designed that no bilge water or dirt can enter therein. An oil trough is thus formed at the base of each engine to catch all the oil. A small pump* is provided in the starboard engine room, with suction connections to the bottom of each crankpit oil well, for pumping out any water that may have collected from the oil or through leakage. This pump discharges to the bilge. The entire engine is incased with a light galvanized sheet-steel casing, to prevent splashing and waste of oil, which is carried up to within about eighteen inches of the bottoms of the cylinders.

*See Table II.

The plant operates as follows: One pump draws the oil from the settling and cooling tanks, and discharges same through a pipe, fitted in duplicate for emergencies, having branches to the main bearings through holes in the caps. An annular groove in the center of each main bearing provides for the proper distribution of the oil, part of which lubricates the bearings, the balance passing through a radial hole in each journal, in wake of the groove, to the crankshaft axial holes, the openings at ends of each axial hole being closed by oiltight cover plates. From the axial holes the oil is forced through radial holes to the eccentric straps and crank-pin axial holes, and through radial holes to the surface of the crank pins. The crank-pin bearings are similarly grooved to the main bearings, all oil not used for crank-pin lubrication passing up through brass tubes secured to the connecting rods, to the crosshead bearings. After performing its function the oil escapes at the ends of the bearings and drains to the crank pit, where it collects in the drain well and is pumped by a second pump, through oil filters, to the main supply and settling tanks, thus completing its cycle, which is indefinitely repeated as described. The third pump is a standby for emergencies and connected to perform the duties of either of the other two pumps.

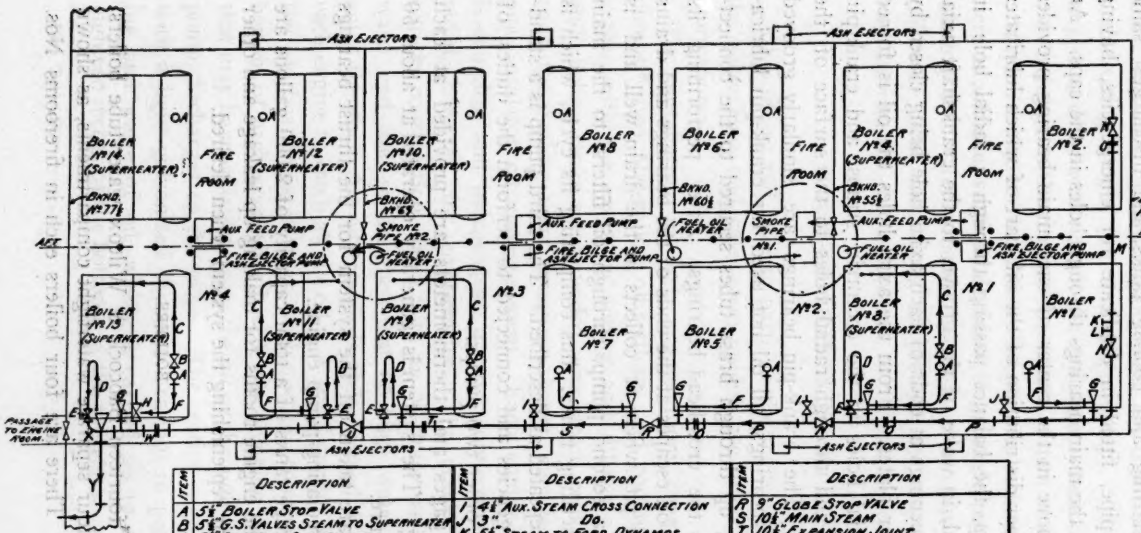
Pressure gages and thermometers are provided at each main bearing. The system is generally operated at about 50 pounds pressure.

Branches are taken off the system for the thrust bearings and main circulating-pump engine.

Large storage tanks of a total capacity of 2,000 gallons are installed in the engine rooms for making up leakage and other waste, and for replenishing the system when desired.

BOILERS.

There are fourteen Babcock & Wilcox water-tube boilers, arranged in four separate watertight compartments, as shown in Plate II. There are four boilers each in firerooms Nos.



ITEM	DESCRIPTION	ITEM	DESCRIPTION	ITEM	DESCRIPTION
A	5⅛" Boiler Stop Valve	I	4½" Aux. Steam Cross Connection	R	9" Globe Stop Valve
B	5⅛" G.S. Valves Steam to Superheater	J	3" Do.	S	10½" Main Steam
C	5⅛" Steam to Superheater	K	5⅛" Steam to Ford. Dynamos	T	10½" Expansion Joint
D	5⅛" Steam, Superheater to Main Line	L	4½" Steam to Windlass	U	12" Globe Stop Valve
E	5⅛" G.S. Valve, Do.	M	7" Main Steam Cross Connection	V	14" Main Steam
F	5⅛" Steam, Boiler to Main Line	N	7" Globe Stop Valve	W	14" Expansion Joint
G	5⅛" A.S. Valve, Do.	O	7" Expansion Joint	X	14½" Angle Stop Valve
H	7" Aux. Steam Cross Connection	P	7" Main Steam	Y	14½" Main Steam to Engine Room

Note.- Steam Piping on Port Side Similar to That Shown.

U. S. S. "NEW YORK."—ARR'G'T. OF MAIN STEAM PIPING AND MACHINERY IN BOILER ROOMS.—PLATE II.

1, 3 and 4, and two boilers in fireroom No. 2. Eight of the boilers, Nos. 3 and 4, and 9 to 14, inclusive, are fitted with superheaters.

The boilers are designed to operate the entire machinery plant at full power, with an average air pressure in the ash pits of not more than two inches of water. They are equipped primarily for burning coal, but are provided with an auxiliary installation for burning fuel oil in combination with coal.

The uptakes are of the usual design, and there are two smoke pipes, each 92.17 feet high above the grates. The forward smoke pipe is 11 feet 2 inches and the after one 12 feet 9 inches inside diameter, the former serving six and the latter eight boilers. Both smoke pipes are 13 feet 5⅜ inches outside diameter.

Boiler Data.

Number		14
Pressure, working, pounds per square inch		295
test, pounds per square inch		450
Height to top, external, feet and inches	Twelve of	12–00⅞
	Two of	11–09¼
Length on floor, feet and inches	Twelve of	10–01
	Two of	9–01½
Width on floor, feet and inches		17–02½
Drum, diameter, inside, inches		42
length, feet and inches		17–09⅞
thickness, inch		00$\frac{11}{16}$
Number of furnaces, each boiler		1
furnace doors, each boiler		4
Grates, length, feet and inches		7–00
width, feet and inches		15–10.32
per cent. of air space through		49
Total grate surface, square feet		1,554
heating surface, generating, square feet		62,213
superheater, square feet		3,267
Ratio, G.S. to H.S. (generating)		1 to 40.03
Number of tube headers, each boiler		27
2-inch tubes, each boiler		863
4-inch tubes, each boiler		29
Distance between headers, feet and inches	Twelve of	9–00
	Two of	8–00
Area through smoke pipe, forward, square feet		97.94
aft, square feet		127.68

G.S. ÷ area through smoke pipe, forward	6.687
aft	6.955
Kind of forced draft	Closed firerooms.
Oil burners, number each boiler	6
type	Peabody.
Diameter of main steam stop valve, inches	05½
main and auxiliary feed, stop and check valves (one of each), inches	02½
surface-blow valve, inches	01½
bottom-blow valves (two), inches	01½
safety valve, twin, inches	04½

FUEL—OIL SYSTEM.

In addition to the usual coal-burning equipment, a complete oil-burning system is provided, for use as auxiliary fuel to be burned as required in combination with the coal.

The plant consists of two heavy-pressure, vertical, double-acting, single, pumps,* one in each engine room to the center-line bulkhead. These pumps draw the fuel oil from the double-bottom tanks, and deliver same to the oil burners on the boilers. Each boiler is fitted with six oil burners, mechanically atomized, of the Peabody type.

A 4½-inch suction pipe leads from the bottom of each tank to the suction manifolds located near the pumps in each engine room. The pump suctions from manifolds are 5 inches in diameter each, and are each fitted with a Macomb strainer. The discharge from each pump is 3½ inches in diameter, uniting into a common 3½-inch pipe (either pump being capable of supplying the entire system) which leads to the firerooms. The 3½-inch main is fitted with a Lalor automatic stop valve at junction with discharge pipes from both pumps.

In the firerooms the main is led forward, gradually decreasing in size from 3½ to 2 inches. There is a 1½-inch branch, taken off the main in each fireroom, leading to the fuel-oil heater in same fireroom. Each heater has 25.1 square feet of heating surface, the heating agent being live steam. By-passes are provided around the heaters. Each heater discharge pipe is 1½ inches, dividing into ¾-inch branches, fitted with

*See Table II.

Lalor automatic stop valves, to the burners on individual boilers.

Each fuel-oil tank is provided with a 1½-inch steam connection led to the bottom of the tank, for boiling out, and a 1-inch steam fire extinguishing connection at the top of tank.

Provision is made whereby the fuel-oil pump can transfer the fuel oil, through the filling pipe, to another vessel in emergency.

For washing out the tanks, one fire and bilge pump in each engine room is arranged for pumping their contents overboard, the connection for flooding and pumping out being portable and only connected up when cleaning the tanks, so there is no danger of flooding the tanks with sea water.

PNEUMERCATOR SYSTEM.

For ascertaining at any time the amount of fuel oil in the various double-bottom tanks, the Parks Pneumercator system is installed.

The installation consists of a small semi-spherical balance chamber placed at a predetermined location near the bottom of each tank. The interior of the balance chamber is in communication with the tank, through a hole in the side of the chamber, and a small pipe connects the top of the chamber with its recording instrument in the engine room at the fuel-oil manifold. The recording device consists of a glass mercurial tube provided with scale, calibrated to suit the tank to which it is connected.

The instrument operates on the following principle. The pressure due to the head of oil in the tank compresses the air in the chamber and connecting pipe line, which in turn causes the mercury to rise or fall in the tube in direct ratio to the pressure exerted. The tank contents is read off on the scale, as in the case of an ordinary thermometer.

In order to guard against overflowing the tanks when taking aboard fuel oil, an annunciator is installed in connection

with the recording device for indicating and signaling when any tank is 95 per cent. full.

The report of the engineer officer, on the operation of the instrument during the first six months of the commissioning of the vessel, pronounces it entirely satisfactory. A careful checking of its readings on various tests aboard the vessel have shown that it is thoroughly reliable. During the recent final-acceptance trials, when running the two-hours full-power run, burning oil and coal, the oil was measured by special measuring tanks on deck, which record agreed exactly with the pneumercator readings.

FIREROOM AUXILIARIES.

Forced-Draft Blowers.—Firerooms Nos. 1, 3 and 4 have four forced-draft blowers each, and fireroom No. 2 has but two. They are located in specially constructed blower rooms just below the protective deck and above the working flat in front of the boilers.

The fans are of the Sturtevant multivane type, and each is electric driven by a direct-connected 26-H.P. Diehl motor, controlled from the fireroom working level and the blower room at will. Air is supplied from the fireroom ventilators, which are closed at the bottom when under forced draft. The blowers are designed to run at 650 to 825 r.p.m.

**Auxiliary Feed Pumps.*—There are four Blake, vertical, double-acting, single, auxiliary feed pumps, one in each fireroom. They are arranged so that any pump can feed any boiler.

**Fire, Bilge and Ash-Ejector Pumps.*—In each fireroom there is a Blake, vertical, double-acting, duplex pump for fire, bilge and ash-ejector service. They are arranged to draw from the drainage system and sea, and discharge to the fire main, sanitary system, ash ejectors and overboard.

Ash Hoists.—The port ventilator in each fireroom is fitted for hoisting ashes, the necessary bucket guides, wire ropes,

*See Table II.

sheaves, etc., being installed for the purpose. The hoists are operated from the main deck, at which deck the ash chutes are located at the ship's side.

The four ash-hoist engines, one for each hoist, are of the two-cylinder, reversible type, made by the Hyde Windlass Co. They are located in the upper fireroom hatch and are of the following principal dimensions:

Number of cylinders, each	2
Diameter of cylinders, inches	4½
Stroke, inches	4½

Ash Ejectors.—In addition to the ash hoists, there are eight 6-inch hydraulic ash expellers, two in each fireroom, port and starboard, discharging the ashes through scuppers above the protective deck.

MAIN STEAM PIPING.

The main steam piping is arranged in two symmetrical systems, one on each side of the vessel. The two lines are cross-connected in the forward fireroom and in the engine rooms by 7- and 9-inch connections, respectively. The branches from the boilers are 5½ inches in diameter each, and the lines proper are 7 inches in the forward fireroom, increasing to 9, 10½, 12 and 14 inches at each successive boiler connection. The pipes are increased to 14½ inches through the pipe passages between the engine and firerooms, reducing again to 14 inches in the engine rooms beyond the separators, which size continues to the throttle valves.

The arrangement of valves in the main steam piping is shown in Plates I and II.

AUXILIARY STEAM PIPING.

From the main steam pipe in the engine rooms is a 6-inch connection, with stop valve, which leads aft through the engine rooms and through the center-line bulkhead, with stop

valve on either side of same, forming a connecting loop between the two sides of the ship. From this pipe steam connections are taken for the various engine-room auxiliaries, steering engine and heating system aft. For use in port, when steam is shut off the main steam lines to engine rooms, there is a 4-inch auxiliary steam pipe, starboard side only, with stop valve at each end, from the auxiliary steam cross-connection in the after fireroom, which supplies steam to the auxiliary steam line in the engine rooms.

In the firerooms the auxiliary steam piping consists of a cross-connection, with stop valve at each end, between the port and starboard main steam lines, from which the branches to the auxiliaries are taken. The cross-connections are 3, 4½ and 4 inches in diameter, respectively, for firerooms Nos. 1, 2 and 3, and 7 inches in fireroom No. 4, which supplies the after dynamo room and distilling apparatus.

The forward dynamos and windlass take their steam off the main steam cross-connection in the forward fireroom.

Stop valves are fitted in all branches and sub-branches as required.

AUXILIARY EXHAUST PIPING.

An auxiliary exhaust pipe is fitted throughout the machinery spaces and elsewhere as required for the various auxiliaries. Connections are provided to direct the exhaust steam into either main or auxiliary condensers, either feed-water heater, or into the atmosphere through the after escape pipe at will. There are also connections for admitting the exhaust steam to the L.P. receivers.

Stop valves are fitted in all branches at the main.

MAIN AND AUXILIARY FEED SYSTEMS.

Each main feed pump has a 5½-inch independent suction from the main feed tank in same engine room. The pumps discharge *via* the feed-water heaters, or by-pass same if desired, to the boilers. The combined discharge from each pair

of pumps is 6 inches, uniting in the after fireroom into an 8-inch connection leading forward and diminishing in size as it advances to 5 inches in the forward fireroom.

The auxiliary-feed suction main is taken off the 8-inch feed tank's cross-connecting pipe. This main is 9 inches in diameter, reducing in size to 5½ inches, as it leads forward to the auxiliary feed pumps, each pump having a 5½-inch suction connection. The auxiliary feed pumps discharge direct to the boilers in their respective compartments, or into the main feed line to any boiler. The discharge connections are 4½ inches in diameter at the pumps.

All branch, main and auxiliary feed pipes to the boilers are 2½ inches in diameter.

INTERIOR COMMUNICATION.

The customary engine and fireroom telegraphs, gongs, time-firing device, telephones, voice tubes, etc., are fitted for transmitting orders and signaling to the various machinery compartments and other parts of the vessel.

AIR-COMPRESSOR PLANT.

Located in each engine room are four 11-inch by 11-inch by 12-inch water-cooled Westinghouse steam-driven air compressors and two air reservoir tanks of about 45,000 cubic inches capacity each, for use in running pneumatic tools in the engineering department, blowing soot off the boiler tubes and for the gas-ejecting system for the guns.

Each compressor has a capacity of about 360 cubic feet of free air per minute at 150 pounds pressure.

A pneumatic main, independent of the gun gas-ejecting system, is led throughout the machinery space, with branches to the general workshop, evaporator and dynamo rooms, from which the connections for pneumatic tools and blowing soot off boiler tubes are taken.

EVAPORATING AND DISTILLING APPARATUS.

This plant is located on the protective deck, just forward of barbette No. 3. There are four evaporators, two distillers, two feed-water heaters, two distiller circulating pumps,* two evaporator feed pumps* and two fresh-water pumps,* together with their accessories. The plant has a combined capacity of 28,000 gallons of water per 24 hours, and is arranged to operate in double effect.

Evaporator Data (each).

Type	Reilly, horizontal, multi-coil.
Diameter, inside, feet and inches	5–01½
Length, over all, feet and inches	5–02½
Coils, number	36
diameter of pipe, inch	01
thickness of pipe, inch	00.065
Heating surface, square feet	221.4
Diameter of steam connection, inches	03
vapor nozzle, inches	04½
feed valve, inches	01¼
blow valve, inches	02½

Distiller Data (each).

Type	Reilly, vertical, multi-coil.
Diameter, inside, inches	31
Length, over all, feet and inches	4–03⅜
Coils, number	15
diameter, inch	01
thickness, inch	00.065
Cooling surface, square feet	92.25
Diameter of circulating water inlet and outlet, inches	04½
vapor inlet, inches	04½
drain, inches	02

Evaporator Feed-Water Heater Data (each).

Type	Bureau, made by Griscom-Russell Co.
Tubes, number	28
diameter, inside, inch	00¾
thickness, inch	00.065
Heating surface, square feet	19
Diameter of feed inlet and outlet, inches	02
vapor inlet and outlet, inches	04½

*See Table II.

GENERAL WORKSHOP.

A well-equipped machine shop is located amidship, on the protective deck, between the engine-room hatches.

The following machine tools, each driven by its own electric motor and all up to date and complete with the most modern attachments, are installed as listed below:

No.	Description.	Make and H.P. of Motor.
1	28-inch by 48-inch swing, extension-gap lathe; E. Harrington and Sons Co.	Reliance, 7½ H.P.
1	14-inch swing lathe; The American Tool Works Co.	Reliance, 3 H.P.
1	14-inch swing lathe; The American Tool Works Co.	Reliance, 2 H.P.
1	16-inch column shaper; John Steptoe Shaper Co.	Reliance, 2 H.P.
1	31-inch simplex radial drill; Dreses Machine Tool Co.	Reliance, 2 H.P.
1	16-inch sensitive drill; Willey	Reliance, ½ H.P.
1	Universal milling machine; The Hendey Machine Co.	Reliance, 1 H.P.
1	Floor grinder; Willey	Reliance, 1 H.P.
1	Portable cylinder-boring machine; H. B. Underwood and Co.	2 H.P.
1	Planer	1½ H.P.
1	Bridgeport grinder	1 H.P.

BLACKSMITH SHOP.

A blacksmith shop is provided on the main deck, in the deck house, abreast of the after smoke pipe, port side. It is equipped with one portable and one permanent forge, together with anvil and all necessary tools and fittings. The permanent forge is fitted with an electrically-driven blast fan.

FOUNDRY.

A small foundry is installed in the deck house on the main deck. The foundry outfit consists of a small oil-burning crucible furnace of the Bureau's standard type, together with adequate allowance of crucibles and the necessary apparatus for handling and pouring the metal.

ELECTRIC PLANT.

There are two dynamo rooms, one just forward of the forward boiler room and the other just aft of the after boiler room. They are on the lower platform level, with their condensing apparatus below in a separate room in the hold, there being an access hatch and ladder between the two levels.

The distribution rooms, two in number, are located on the upper platform, one over each dynamo room. They contain the lighting, power and searchlight distribution boards only. The generator boards are in the dynamo rooms.

The generator installation consists of four 6-pole, compound-wound, 300-kilowatt, General Electric generators, two in each dynamo room, each driven by a two-stage horizontal Curtis turbine. Each generator will deliver at normal load 2,400 ampères of current at 125 volts, when running at 1,500 revolutions per minute. The generators are capable of delivering one-third overload for two hours without injury.

There is one condenser for each pair of generators of the same general design as the main and auxiliary condensers. Each condenser has its independent air pump,* centrifugal circulating pump,* hotwell-tank pump,* and a hotwell tank.

Dynamo Condenser Data.

Number	2
Inside diameter, feet and inches	4–05½
Thickness of shell (steel), inch	00⅜
Length between tube sheets, feet and inches	8–05⅜
Thickness of tube sheets, inches	01⅛

*See Table II.

Tubes, number	1,745
diameter, outside, inch	005/8
thickness, inch	00.065
Cooling surface, square feet	2,400
Diameter of exhaust nozzles (2), inches	20
air-pump suctions, inches	07
circulating-water inlet and outlet, inches	08

Dynamo-Condenser Air Pumps Data.

Number	2
Type	Blake, vertical, twin, beam, single steam cylinder.
Diameter of suction nozzle, inches	07
discharge nozzle, inches	06
steam cylinder (1), inches	09
water cylinders (2), inches	18
Stroke, inches	12

Dynamo-Condenser Circulating Pumps and Engines Data.

Number	2
Type	Double-inlet centrifugal, driven by single engine.
Diameter of impeller, inches	26
suction (2), inches	053/4
discharge, inches	08
steam cylinder, inches	06
Stroke, inches	05

TRIALS.

The *New York* was subjected to the following trials in order to prove her machinery, ability to attain the designed speed and to ascertain her fuel and water consumption at the various speeds:

(*a*) A progressive trial over a measured-mile course in deep water for standardizing the screws, extending from maximum speed down to a speed of about ten knots.

(*b*) A full-speed trial of four hours' duration in the open sea in deep water, at the highest speed attainable. (Designed speed 21 knots, with the air pressure in the firerooms not exceeding an average of 2 inches of water, and the steam pressure in the H.P. steam chest not exceeding 265 pounds above the atmosphere.)

*See Table II.

TABLE II - PUMPS AND CONNECTIONS - U.S.S. NEW YORK.

No.	Pumps	Size (Ins.)	Type	Suction Pipes From -	Ins.	Discharge Pipes To -	Ins.	Location
2	Main Air	(2) 14 x (2) 35 x 21	Blake, Twin, Vertical, Single-Acting	Condenser	12	Feed Tank	10	1 in each Eng. Room
2	Main Circulating	42 Impeller; 10-20 x 10 Eng.	Horizontal, Centrifugal; Vert. Compound Eng.	Sea Main Drain	(2) 17 15½	Condenser Water Service	23 4	Do.
4	Main Feed	15½ x 9½ x 24	Blake, Vert., Double-Acting, Single	Feed Tanks Channel Way Cross Connection	5½ 5½	Main Feed Line	5	2 in each Eng. Room
4	Aux. Feed	Do.	Do.	Feed Suction Pipe Ship's Sides (a) Reserve Fd. Tanks Hose Connection	5½ 4 4 2½	Main Feed Line Reserve Fd. Tanks (b) Each Boiler in Compt. with Pump.	5 3½ 2½	1 in each Boiler Room
4	Fire and Bilge	12 x 10 x 18	Do.	Sea Drainage Hose Connection Fuel Oil Tanks (c)	5 5 1½ 4½	Fire Main Overboard Sanitary Main (b) Hose Connection	5 5 5 2½	2 in each Eng. Room
4	Fire, Bilge and Ash Ejector	14 x 8 x 12	Blake, Vert., Double-Acting, Duplex	Sea Drainage Hose Connection Do.	6 5 1½ 2½	Fire Main Overboard Sanitary Main Ash Ejectors Hose Connection	5 5 5 4½ 2½	1 in each Boiler Room
4	Forced Lub. Service	7 x 8 x 8	Blake, Vert., Double-Acting, Single	Oil Tanks Oil Well (d)	3½ 3½	Settling Tanks (d) Main Bearings	3 2½	2 in each Eng. Room
2	Forced Lub. Return	Do.	Do.	Oil Well	4	Settling Tanks	3½	1 in each Eng. Room
1	Oil Well Drain	2 x 1½ x 2½	Blake, Vert., Duplex, D-Acting	Oil Well	1	Bilge	2½	Starb'd. Eng. Room
2	Fuel Oil Supply	14 x 9 x 12	Blake, Vert., Double-Acting, Single	Storage Tanks Ship's Sides	5 5	Burner Supply Storage Tanks Overboard	4½ 4½ 4½	1 in each Eng. Room
2	Aux. Air	7½ x 14 x 12	Do.	Aux. Condenser	6	Main Feed Tanks	4	Do.
2	Aux. Circulating	28 Impeller; 5 x 4 Engine	Hor. Centrifugal, Vert. Single Eng.	Sea	5	Aux. Condenser	5	Do.
2	Dynamo Cond. Air	9 x (2) 18 x 12	Blake, Twin, Vert., Single-Acting	Dynamo Cond.	7	Dynamo Room Hot Well Tank	6	1 in each Dyn. Cond. Room
2	Dynamo Cond. Circ.	26 Impeller; 6 x 5 Engine	Hor. Centrifugal, Vert. Single Eng.	Sea	(2) 5½	Dynamo Cond.	8	Do.
2	Dyn. Rm. Hot Well	4½ x 5 x 6	Blake, Vert., Double-Acting, Single	Dyn. Room Hot Well Tank	2½	Aux. Feed Suction Main	2	Do.
2	Evaporator Feed	Do.	Do.	Sea Dist. Circ. Disch.	2½ 2½	Evaporators	2	Evap. Room
2	Distiller Circ.	8 x 12 x 12	Do.	Sea	6½	Distillers Fire Main	6 4½	Do.
2	Distiller Fresh Water	4½ x 5 x 6	Do.	Distillers	2½	Fresh Water Tanks Aux. Fd. Suction Reserve Fd. Tanks	2 1½ 1½	Do.
2	Pipe Insulator Circ.	7 x 8 x 12	Do.	Sea	4½	Pipe Insulators	4	1 in each Eng. Room
1	Reserve Feed	4½ x 5 x 6	Do.	Reserve Fd. Tanks	3	Main Feed Tanks Air Comp. Circ. Main	2½ 2	Starb'd. Eng. Rm.
2	Shaft. Bilge	9 x 6	Plunger, Single-Acting	Eng. Room Bilge Shaft Alley	4½ 4½	Overboard	4½	1 in each Shaft Alley
3	Brine Circ.		Hor., Cent., Motor Driven	Brine Suction	3	Brine Discharge	3	Main Ice Mach. Rm.
2	CO_2 Cond. Circ.		Do.	Sea	3	CO_2 Condenser	2½	Do.
1	Brine Circ.		Do.	Brine Suction	1½	Brine Discharge	1½	Ford. Ice Mach. Rm.
1	CO_2 Cond. Circ.		Do.	Sea	1½	CO_2 Condenser	1¼	Do.
2	Flushing		Do.	Sea	6	Crew's Ind. San. Itar System	5	Comp'y's D26. P. & S.
2	Fresh Water	(3) 4 x 6	Triple Plunger, Motor Driven	Fresh Water Tanks	2½	Fresh Water System	2½	Windlass Eng. Rm.

(a) No. 3 Fire Rm. only. (b) One Pump in each Eng. Rm. (c) Portable Connection. (d) One Pump in each Eng. Rm.

(*c*) An endurance and coal-and-water-consumption trial of twenty hours in the open sea in deep water at a speed of 19 knots as nearly as possible. All necessary auxiliaries usually required under service cruising conditions, the distilling plant excluded, to be in operation.

(*d*) An endurance and coal-and-water-consumption trial of twenty hours in the open sea at an average uniform speed of 12 knots as nearly as possible, with conditions similar to Trial (*c*).

(*e*) A trial of two hours' duration at the highest speed attainable, burning coal and oil fuel in combination.

The fuel consumption was carefully measured on Trials (*b*), (*c*), (*d*) and (*e*), and also the water consumption on trials (*b*), (*c*) and (*d*).

Standardization Trial (*a*).—This trial was run on the measured-mile course off Rockland, Maine, on October 20, 1914. The weather conditions were excellent.

After completing twenty successful runs, the trial was interrupted on the twenty-first run, due to a hot valve-stem crosshead guide on the after L.P. cylinder, starboard engine, which necessitated slowing the engines, and the trial was discontinued.

On the following day a fog set in, obscuring the ranges and making it impossible to continue further standardization runs without a probable long delay; and as the data obtained were, in the opinion of the Board exceptionally accurate and sufficient for the construction of a satisfactory curve, it was considered that an indefinite delay to obtain further runs for the high spot on the curve was not justified.

The data obtained on the twenty runs over the measured mile are given in Table III, from which the curves, Plate III, were plotted.

The official speed and revolution curve gave the following mean revolutions per minute of the main engines as necessary to attain the speeds desired for trials (*b*), (*c*) and (*d*):

TABLE III - STANDARDIZATION TRIAL DATA - OCT. 20, 1914 - U.S.S. NEW YORK

No. of Run	Time on Course		Speed in Knots	Revs. to go One Knot			R.P.M.			I.H.P.		
	Mins.	Secs.		Star. Engine	Port Engine	Mean	Star. Engine	Port Engine	Mean	Star. Engine	Port Engine	Total
1	5	34.0	10.78	331.0	329.6	330.3	59.47	59.20	59.34	1422	1277	2699
2	5	35.5	10.73	331.0	332.7	331.7	59.25	59.57	59.41	1435	1474	2909
3	5	40.9	10.56	337.6	339.9	338.8	59.41	59.80	59.61	1404	1465	2869
Mean of Group			10.70						59.44			2847
4	4	41.7	12.78	325.4	332.4	328.9	69.31	70.80	70.06	2258	2109	4367
5	4	54.2	12.24	341.0	341.3	341.2	69.54	69.60	69.57	2144	2173	4317
6	4	45.6	12.61	331.2	324.4	327.8	69.59	68.16	68.88	2162	2096	4258
Mean of Group			12.47						69.52			4315
7	3	55.8	15.27	340.8	332.4	336.6	86.72	84.56	85.64	4036	3895	7931
8	3	56.0	15.25	338.8	340.2	339.5	86.16	86.51	86.33	3926	4445	8371
9	3	49.8	15.67	332.4	330.1	331.3	86.82	86.22	86.52	3970	4340	8310
Mean of Group			15.36						86.21			8246
10	3	30.2	17.13	348.6	350.1	349.4	99.54	99.98	99.76	6247	6726	12973
11	3	23.8	17.66	339.5	333.8	336.7	99.94	98.27	99.11	6292	6140	12432
12	3	34.3	16.80	353.3	349.6	351.4	98.91	97.88	98.40	6123	6194	12317
Mean of Group			17.31						99.10			12539
13	3	5.8	19.38	337.6	331.3	334.5	109.08	107.03	108.06	8464	8037	16501
14	3	15.6	18.14	356.8	354.3	355.6	109.46	108.70	109.08	8593	8426	17019
15	3	4.4	19.52	332.9	334.9	333.9	108.30	108.95	108.63	8507	8829	17336
Mean of Group			18.93						108.71			16969
16	2	57.1	20.33	367.6	363.1	365.4	124.51	122.96	123.73	12834	12654	25488
17	2	45.2	21.79	340.0	341.7	340.9	123.47	124.11	123.79	12695	13804	26499
18	2	58.5	20.17	368.5	365.5	367.0	123.90	122.89	123.40	12357	12807	25164
Mean of Group			21.02						123.68			25913
19	2	40.8	22.39	350.6	344.5	347.6	130.82	128.55	129.68	15954	15831	31785
20	2	53.1	20.80	379.1	373.7	376.4	131.40	129.52	130.46	15965	15928	31893
Mean of Group			21.60						130.07			31839

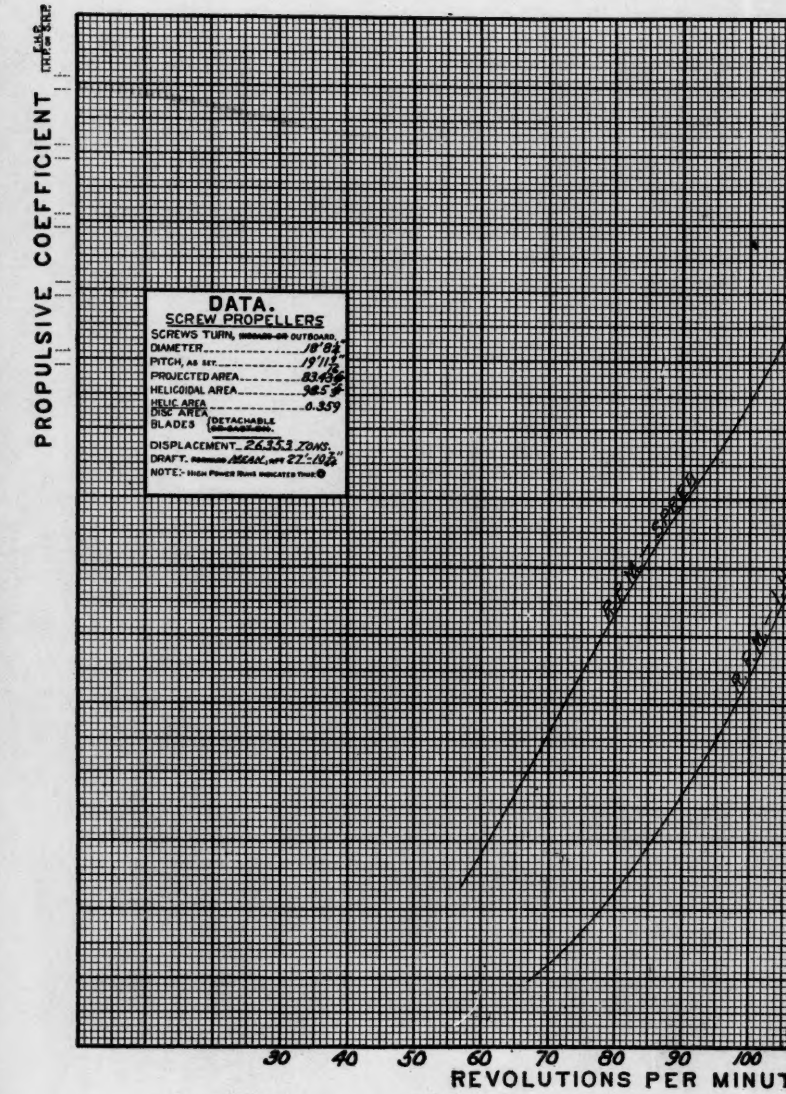
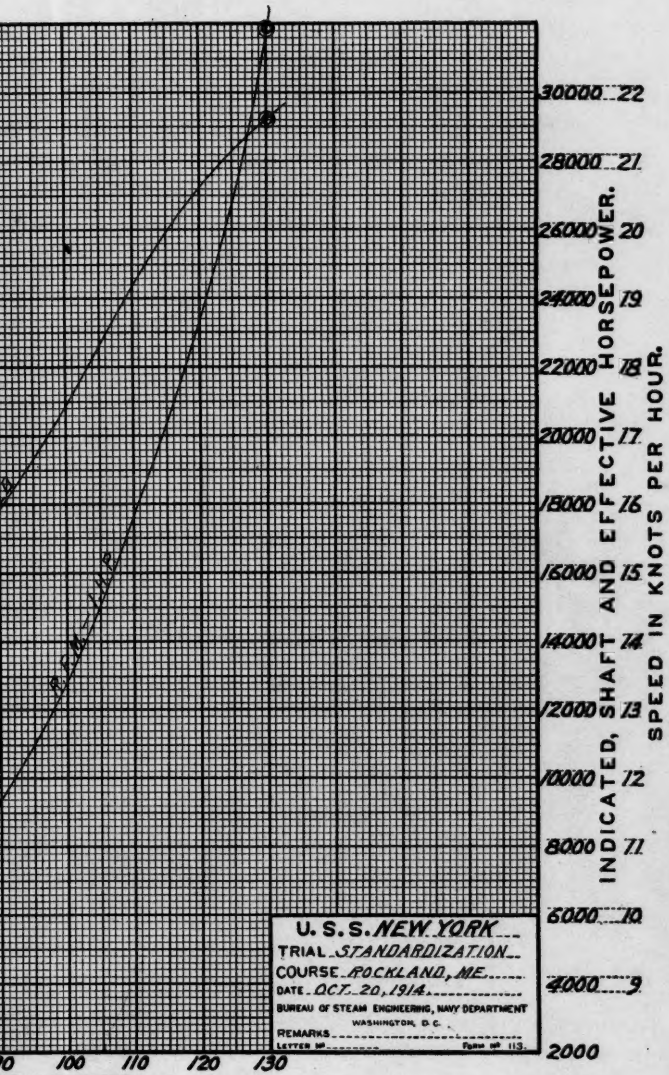

PROPULSIVE COEFFICIENT
DATA.
SCREW PROPELLERS
SCREWS TURN, INBOARD OR OUTBOARD.
DIAMETER 18'8½"
PITCH, AS SET 19'11"
PROJECTED AREA 83.496
HELICOIDAL AREA 98.5
HELIC AREA
DISC AREA 0.359
BLADES (DETACHABLE OR SOLID.)
DISPLACEMENT 26353 TONS.
DRAFT. FORWARD MEAN. AFT 27'-10½"
NOTE:- HIGH POWER RUNS INDICATED THUS
30
40
50
60
70
80
90
100
REVOLUTIONS PER MINUT

PLATE III.


30000 22
28000 21
26000 20
24000 19
22000 18
20000 17
18000 16
16000 15
14000 14
12000 13
10000 12
8000 11
6000 10
4000 9
2000
INDICATED, SHAFT AND EFFECTIVE HORSEPOWER.
SPEED IN KNOTS PER HOUR.
U. S. S. NEW YORK
TRIAL STANDARDIZATION
COURSE ROCKLAND, ME.
DATE OCT. 20, 1914.
BUREAU OF STEAM ENGINEERING, NAVY DEPARTMENT
WASHINGTON, D.C.
REMARKS
LETTER NO
Page No 113.
100 110 120 130
R MINUTE.

TE III.

TABLE IV – U.S.S. NEW YORK – TRIAL DATA.

	4 HOURS' TRIAL (b)	20 HRS.' 19 KTS. TRIAL (c)	20 HRS.' 12 KTS. TRIAL (d)	2 HOURS' COAL & OIL BURNING TRIAL (e)
DATE OF TRIAL	OCT. 22, 1914	OCT. 22 & 23, 1914	OCT. 21 & 22, 1914	OCT. 23, 1914
SPEED IN KNOTS	21.47	19.23	12.11	21.38
DRAUGHT, MEAN ON TRIAL, FEET AND INCHES	27 – 10¼	27 – 7⅝	27 – 8½	
DISPLACEMENT, CORRESPONDING, TONS	26,342	26,094	26,245	
PRESSURES (AVERAGE):	STARBD. | PORT	STARBD. | PORT	STARBD. | PORT	STARBD. | PORT
MAIN STEAM, AT BOILERS, POUNDS GAUGE	293.13	267.2	259.4	289.71
ENGINES, DO.	272.13 | 280.38	260 | 262.5	258.4 | 263.2	271.1 | 272
H.P. CHEST, DO.	247 | 260.63	216.6 | 224.8	97.45 | 103.75	
1ST RECR., POUNDS ABSOLUTE	98.86 | 95.81	69.8 | 65.3	32.65 | 31.65	
2ND RECR., DO.	29.69 | 30.19	20.2 | 20.3	8.66 | 8.48	
VACUUM, MAIN COND., INCHES OF MERCURY	25.16 | 26.13	26.8 | 28.12	25.77 | 27.81	
BAROMETER, INCHES OF MERCURY	30.02	30.4	29.94	
MAIN FEED, AT PUMPS, POUNDS GAUGE	381.13	353.6	325.42	
AUX. EXHAUST, DO.	5.25	11.75	14.9	
FORCED LUBRICATION, DO.	66.88	56.95	47.18	
FUEL OIL, DO.	NOT USED	NOT USED	NOT USED	230 | 240
STEAM TO FUEL OIL HEATERS, POUNDS GAUGE	DO.	DO.	DO.	
AIR PRESSURE IN FIRE ROOMS, INCHES OF WATER	1.58	1.16	DO.	1.6
MEAN EFFECTIVE PRESSURES, POUNDS (AVERAGE):				
H.P. CYLINDER	107.44 | 123.88	80 | 96.6	29.8 | 38	
I.P. DO.	47.03 | 47.18	35.3 | 34.	17.8 | 14.9	
F.L.P. DO.	17.14 | 18.18	12.2 | 12.	3.76 | 3.8	
A.L.P. DO.	18.33 | 19.	12 | 12.1	3.7 | 3.4	
REFERRED PRESSURE	43.17 | 45.62	30.87 | 32.3	12.08 | 12.01	
REVOLUTIONS OR DOUBLE STROKES PER MIN. (AVER.):				
STARBD. ENGINE	128.59	110.503	67.39	127.87
PORT ENGINE	128.58	110.5	67.43	127.9
MEAN	128.585	110.501	67.413	127.89
MAIN AIR PUMPS	42 | 36.88	34.6 | 27.5	21.16 | 24.3	
CIRCULATING PUMPS	248.88 | 236	222.1 | 209.7	146.95 | 135.1	
FEED PUMPS	(4) 23.69	(4) 16.75	(2) 11.53	
FORCED DRAFT BLOWERS	852.41	737.8	NOT USED	
FUEL OIL PUMPS	NOT USED	NOT USED	DO.	7.5 | 38.3
INDICATED HORSE POWER (AVERAGE):				
H.P. CYLINDER	3,893 | 4,499	2,505 | 3,025	570 | 725	
I.P. DO.	4,565 | 4,536	2,923 | 2,804	902 | 750	
F.L.P. DO.	2,972 | 3,061	1,752 | 1,735	333 | 334	
A.L.P. DO.	3,067 | 3,094	1,733 | 1,747	327 | 301	
TOTAL	14,497 | 15,190	8,913 | 9,311	2,132 | 2,110	
TOTAL BOTH ENGINES	29,687	18,224	4,242	
TEMPERATURES, DEGREES F (AVERAGE):				
MAIN STEAM, AT ENGINES	414.81 | 414.06	409.2 | 413.5	412.25 | 412.2	
STEAM, 1ST RECEIVERS	329.31 | 325.69	* 310.2 | 300.9	* 287 | 254.45	

* TAKEN

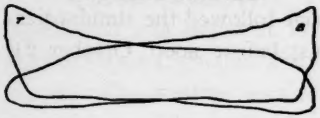
A.L.P. Do.	3,067	3,094	1,733	1,747	327	301	NO OTHER DATA TAKEN
Total	14,497	15,190	8,913	9,311	2,132	2,110	
Total both engines	29,687		18,224		4,242		
Temperatures, degrees F (average):							
Main steam, at engines	414.81	414.06	409.2	413.5	412.25	412.2	
Steam, 1st receivers	329.31	325.69	*310.2	300.9	*287	254.45	
2nd Do.	249	251.88	228	229.6	183.9	180.4	
Superheat, main steam, at engines	6.17	2.75	4.7	8.12	8.31	6.58	
Steam, 1st receivers	2.31	0.94		1.6		1.01	
2nd Do.	0	1.22	0	1.18	0	0	
Main injection	66		70.85		55.48		
Overboard discharge	109.53		96.5		69.55		
Air pumps Do.	94.03		92.8		76.7		
Feed water	190.57		216.8		236.2		
Engine rooms, working level	96.97		98.55		91.18		
Fire rooms, Do.	96		98.13		97.4		
Outside air	62.75		63.1		59.75		
Smoke pipes	617.5		* 547.8		* 387.1		
Fuel oil, to heaters	Not used		Not used		Not used		76
Burners	Do.		Do.		Do.		
Water consumption data:							
Pounds per hour, main engines	442,847		246,742		66,409		
Aux. machinery and drains	52,336		53,296		36,236		
Total	495,183		300,038		102,645		
Main engs., per I.H.P. main engs.	14.917		13.539		15.655		
Total Do.	16.68		16.464		24.197		
Knot run, at	21.47-Kts. 23,064		19.23-Kts. 15,582		12.11-Kts. 8,476		
	21-Kts. 20,420		19-Kts. 15,165		12-Kts. 8,420		
Fuel consumption data:							
Coal, kind	Pocahontas and Colver						
Quality	Very good						
B.T.U. per pound	14,836		14,836		14,836		14,836
Pounds per knot run	2,165		1,660		943		1,163
Hour	46,480		31,920		11,424		24,864
Per I.H.P. main engines	1.566		1.751		2.693		
Sq. ft. of grate	29.91		20.541		12.865		16
H.S.	0.747		0.513		0.316		0.4
Fuel oil, B.T.U. per pound	Not used		Not used		Not used		19,557
Specific gravity at 60° F	Do.		Do.		Do.		0.881
Pounds per hour	Do.		Do.		Do.		17,509
Knot run	Do.		Do.		Do.		819
Pound of coal	Do.		Do.		Do.		0.704
Miscellaneous data:							
Slip of propellers, per cent. own speed (mean)	15.25	15.25	11.67	11.67	8.79	8.84	
Number of boilers in use	14		14		8		14
Grate surface used, sq. ft.	1,554		1,554		888		1,554
Heating surface used, sq. ft.	62,213		62,213		36,116		62,213
I.H.P. main engines per sq. ft. of grate	19.104		11.727		4.777		
Sq. ft. of H.S. per I.H.P. main engines	2.096		3.414		8.514		
C.S. (main cond.) per I.H.P. main engs.	0.8154		1.433		6.178		
Knots per ton of coal	1.035		1.35		2.375		
Cut-off:							
H.P. cylinder	Full	Full	0.68	0.68	0.56	0.56	
I.P. Do.	Do.	Do.	0.70	0.70	0.63	0.63	
F.L.P. Do.	Do.	Do.	Full	Full	0.57	0.57	
A.L.P. Do.	Do.	Do.	Do.	Do.	0.57	0.57	

* Not reliable.

INDICATOR CARDS SET Nº 7 - U.S.S. NEW YORK - FOUR HOURS' TRIAL.

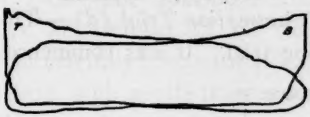
STARBD. ENGINE (129.22 R.P.M.)

H.P. CYL.
M.E.P. 108
M.R.P. 12.15
I.H.P. 3951
SCALE OF SPRING 150

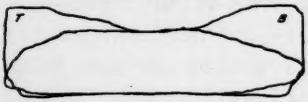


PORT ENGINE (129.21 R.P.M.)

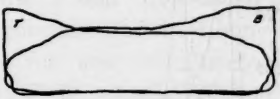
H.P. CYL.
M.E.P. 122
M.R.P. 13.23
I.H.P. 4463
SCALE OF SPRING 150



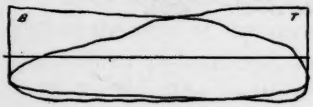
I.P. CYL.
M.E.P. 47.7
M.R.P. 14.06
I.H.P. 4618
SCALE OF SPRING 60



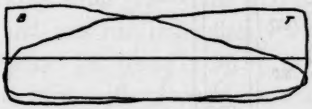
I.P. CYL.
M.E.P. 47.5
M.R.P. 13.63
I.H.P. 4598
SCALE OF SPRING 60



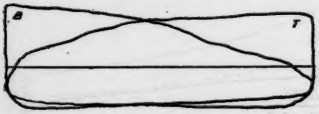
F.L.P. CYL.
M.E.P. 17.8
M.R.P. 8.9
I.H.P. 3002
SCALE OF SPRING 20



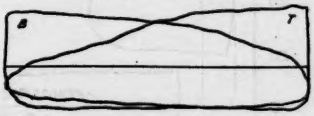
F.L.P. CYL.
M.E.P. 18.5
M.R.P. 9.3
I.H.P. 3120
SCALE OF SPRING 20



A.L.P. CYL.
M.E.P. 18.6
M.R.P. 9.3
I.H.P. 3111
SCALE OF SPRING 20



A.L.P. CYL.
M.E.P. 19
M.R.P. 9.5
I.H.P. 3204
SCALE OF SPRING 20



TOTAL M.R.P. 44.41
TOTAL I.H.P. 14682

TOTAL M.R.P. 45.66
TOTAL I.H.P. 15385

TOTAL I.H.P. BOTH ENGINES 30067

PLATE IV.

Speed, in knots.	R.p.m.
21	123.5
19	109.1
12	66.8

Twenty-Hour 12-Knot Endurance and Coal-and-Water-Consumption Trial (d).—This trial followed the standardization trial. It was commenced just before noon, October 21,

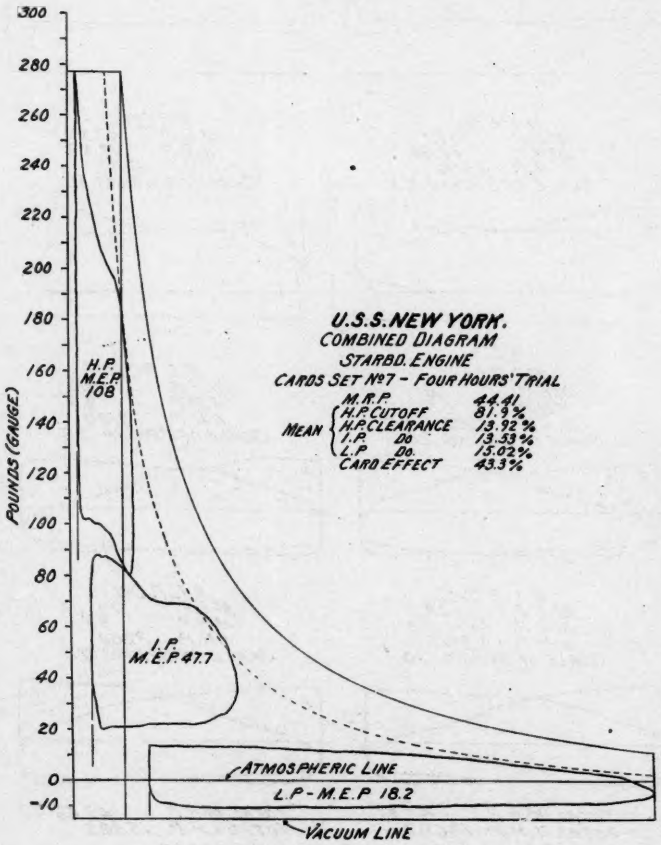


PLATE V

and satisfactorily concluded on the following day. The weather was fair with overcast sky and foggy throughout most of the trial. The average speed was 12.11 knots, and the fuel and water consumption and other data obtained are given in Table IV.

Four-Hour Full-Speed Trial (*b*).—The four-hour full-speed trial was begun at 11:30 A. M., October 22, off Nantucket Shoals Lightship, and was successfully concluded at 3:30 P. M. The weather was very good, with gentle breezes and smooth sea. The designed speed was easily exceeded, the average for the four hours being 21.47 knots.

Table IV gives the data obtained and Plate IV shows indicator cards, set No. 7, taken on this trial. The starboard cards of set are also shown combined in Plate V.

Twenty-Hour 19-Knot Endurance and Coal-and-Water-Consumption Trial (*c*).—Upon conclusion of the 4-hour full-speed trial, the 20-hour 19-knot run was immediately commenced. The trial began at 3:30 P. M., October 22, and was completed at 11:30 A. M., October 23. The trial was run in varying conditions of wind and sea, but not unfavorable. An average speed of 19.23 knots was maintained, and the data is given in Table IV.

Two-Hour Coal-and-Oil-Burning Trial (*e*)—This trial concluded the tests of the vessel, and was run immediately after the 20-hour 19-knot trial, on October 23, from 11:30 A. M. to 1:30 P. M. The weather was fair, with moderate sea and breezes. For data see Table IV.

All trials were conducted with the regular navy crew, the vessel being in commission when the trials were run.

TURBINE ELECTRIC PROPULSION OF A BATTLESHIP COMPARED WITH OTHER MEANS.

By P. W. Foote, Lieutenant Commander, U. S. N.

The introduction of forced oil lubrication for reciprocating engines so greatly removed the trouble of hot bearings at high speed that the turbine engine lost a great deal of its superior value for uses on a battleship, as in many other important points the turbine was no better and in a number not so good as the reciprocating engine. This was very ably demonstrated in a paper prepared by Captain C. W. Dyson, U. S. N., entitled, "Engineering Progress in the U. S. Navy," and read before the Society of Naval Architects and Marine Engineers, November, 1913 (see Volume 20 of the Transactions of the Society). In this paper certain requirements were tabulated which necessarily governed the selection of the propelling machinery of heavy vessels of moderate speeds, in which class a battleship falls. The U. S. S. *Delaware* was chosen as the model of a battleship with reciprocating engines, and her performances were compared with those of her sister ship, the *North Dakota*, driven by Curtis turbines, direct-connected to propeller shafts, and also with those of the U. S. S. *Utah*, having direct-connected Parsons turbines.

Captain Dyson's paper showed the reciprocating engines to be more advantageous for use in battleships in the U. S. Navy than the turbine, in the following characteristics:

(*a*) Greater economy in low speeds, hence greater cruising radius.

(*b*) Ease of up-keep of machinery, allowing greater readiness for duty.

(*c*) Efficient propellers for maneuvering, and high backing power.

(*d*) Weight and space.

(*e*) Minimum vibration of hull due to machinery, and steadiness of hull as a gun platform.

In the following particulars the reciprocating engine and the turbine were shown to be about equal:

(*a*) Economy at maximum speed when this does not exceed twenty-two knots.

(*b*) Reliability when driven at high powers.

(*c*) Boiler weight and space.

The only condition in which the turbine was considered superior to the reciprocating engine was in case the necessary power to be developed were greatly increased from that at present and if the ordinary cruising speed were made considerably higher than now used.

The above characteristics cover the important and controlling features of the propelling machinery for a battleship, and the discussion under the different headings showed good reason why reciprocating engines were preferred to turbines for the *New York*, *Texas* and the *Oklahoma*.

It being generally accepted that rotary motion for an engine is preferred to reciprocating, the question naturally arises, "Is there any way in which the turbine engine may be used for battleship propulsion and at the same time equal or improve the efficiency of the reciprocating engine in the above-mentioned particulars in which it is now considered inferior?" This question is a particularly important one, due to the increase in power now being required, causing the turbine to be superior in weight and space, as mentioned by Captain Dyson on page 58 of his paper.

The answer to the above question seems to depend upon finding an efficient means of transmitting the power of the steam turbine to the propeller shafts with little loss of power but with a great reduction of speed in r.p.m., this being due to the fact that it is fundamental in the "nature of the beast" that a steam turbine only reaches its greatest efficiency at a

very high speed in r.p.m., these speeds varying from 1,200 to to 3,600 r.p.m., depending upon the power developed, and, by the same token, the efficient speed of a propeller is very low, being about 100 to 125 r.p.m.

There are now two means, for which great merit is claimed, by which the speed of the turbine may be reduced and the power transmitted to the propeller with a high efficiency. These two means are (1) mechanical reduction gear, (2) electrical transmission, using electric generators and motors.

There is also the Föttinger hydraulic gear, proposed for this purpose, but it is probably only good for limited speed reduction. We will, therefore, only consider the other two.

The mechanical reduction gear is in use in the U. S. S. *Neptune*, where about 2,500 S.H.P. is transmitted on each of two gears from a Westinghouse-Parsons turbine running at 1,250 r.p.m. to the propeller running at 135 r.p.m. for maximum speed of 14 knots. This gear is of the modified Melville-Macalpine type, built by the Westinghouse Machine Company.

Most people are familiar with the design of this gear, and it is not necessary to give a description of it here.

The *Neptune's* reduction gear has proven satisfactory, and it has been recommended for further use in ship propulsion. There were some difficulties encountered with the *Neptune's* machinery, but the trouble was not with the reduction gear. This method of speed reduction has found great favor with Sir Charles Parsons, of England, and it was reported in Autumn, 1912, that there were upwards of 100,000 horsepower of Parsons geared turbine machinery built and under construction.

Mr. Charles Curtis also favors the use of the mechanical reduction gear for ship propulsion, and in his discussion of Captain Dyson's paper he stated that in his judgment the best form of propelling machinery for the next United States battleship would be straight turbines, combined with small cruising geared turbines, the latter to be used only at low power, and on long cruises where economy of coal was of prime importance. When the cruising turbines were in use,

the steam would pass first through the geared turbine and then through the main turbines. He predicted a large gain in economy, "at least 25 per cent.," at speeds of 10 or 12 knots. It is interesting to note that the design of the *Pennsylvania* follows almost exactly the above outline, and her performances will be awaited with much interest.

On March 13, 1913, Sir Charles Parsons read a paper on "Mechanical Gearing for the Propulsion of Ships" before the Institute of Naval Architects (London), the effect of the paper being to give an account of the progress made in developing mechanical gear.

From this paper the following information is obtained: In England there are in actual service cargo steamers, channel steamers and warships using a total of 26,000 H.P. developed by steam turbines and transmitted by the reduction gear. There is under construction 120,000 H.P. of turbine machinery with mechanical reduction gear, of which two installations will be over 20,000 H.P. each. The number of turbine reduction-gear units to transmit this 20,000 H.P. is not stated. It is probably divided into four units, judging by other data given in Sir Charles' paper.

The S. S. *Normannia* and the S. S. *Hantonia*, of 1,900 tons displacement, with a S.H.P. of 5,000 at service speed of 18 knots, operating in the channel service for the London and South-Western Railway Company, have reduction gearing, and they show an economy 40 per cent. greater than the other turbine steamers on the same service, this partly due to increased efficiency of turbines, partly to increased efficiency of propellers due to the lower speed, and partly due to the improved form of vessel incidental to the reduction of boilers and adoption of twin screws—all being due to the use of the reduction gear. After 26,000 knots the *Normannia's* gearing was found to be in perfect condition.

A cargo steamer, the *Cairnross*, sister ship to the S. S. *Cairngowan*, having reciprocating engines, has been fitted with turbine reduction gear developing 1,600 S.H.P., and a coal-consumption trial, in which the coal was same quality and

measured the same way on both ships, the two ships running side by side showed the turbine-reduction gear ship to be 15 per cent. more economical than the one with reciprocating engines.

Sir Charles states that so far no limit in regard to the surface speed of the teeth has been discerned, and that there is no evidence of any limit of power that can be transmitted by mechanical gearing. This applies to the design of the gear itself. There are certain conditions of weight and ease of control which will be mentioned later, which do limit the *application* of mechanical gearing.

The chief difficulty to be overcome in mechanical gearing is to protect the teeth of the gear from unequal and excessive strain due to lack of absolutely perfect alignment of the shafts and their necessary "play" in their bearings. This was accomplished in the Melville-Macalpine gear by the "floating bearings," which are a complicated piece of mechanism. Mr. Parsons states that a means of cutting of double helical teeth has been obtained which, when used with flexible couplings between turbine shafts and their pinions, renders unnecessary the floating bearings.

This last statement is substantiated by experiments conducted by the General Electric Company, who have developed a mechanical gearing which has given extremely satisfactory results without the floating bearings. The degree of the development of this gearing may be illustrated by stating that they recently proposed a turbine and reduction gear for the torpedo-boat tender *Melville* to develop and transmit 4,000 H.P., turbine speed 2,400, propeller speed 110. The weight of the machinery was guaranteed not to exceed 55 tons. This furnished an interesting comparison with the *Cyclops*, *Neptune* and *Jupiter*, as follows:

Cyclops.—Reciprocating engines; weight of machinery, 280 tons.

Neptune.—Turbine with Westinghouse reduction gear; weight of machinery not published.

Jupiter.—Turbine electric; net machinery, 156 tons. The above ships have about 5,500 I.H.P. with twin screws.

The above proposal for the *Melville* was for 4,000 H.P. and single screw, the difference in weight being due to one screw instead of two—1,500 less H.P.—lighter reduction gear due to absence of the floating bearings and lighter turbine per H.P., due to its higher speeds.

This comparison emphasizes the fact that for ships of this size and horsepower the turbine mechanical gear is more advantageous than the turbine electric gear, if the facility of control is not a paramount requirement, though both of these are superior to the reciprocating-engine machinery.

That the advantage lies with the turbine electric gear for ships of greater power and displacement will be shown later, this being particularly the case when facility of control is of great importance, as is the case in a battleship.

When the plans for the propelling machinery of the U. S. S. *Pennsylvania* were being considered, a design for turbine electric propulsion for this ship was made by Mr. W. L. R. Emmett, of the General Electric Company, and the company showed their faith in its successful operation by being willing to guarantee the characteristics, water rates, etc., described later, and in case of failure to meet the guarantees, the company would remove the turbine electric installation without cost to the Government. As the price of this installation would have been approximately $350,000.00, the faith of the company is evident.

For use in illustration and comparison, the following curves and sketches are herewith attached, numbered as shown:

No. 1. Plan of engine room, 31,000 S.H.P., with turbine electric installation as proposed by the General Electric Co.

No. 2. Plan of engine room of a large battleship, 60,000 S.H.P., as proposed by Sir Charles Parsons in his paper above mentioned.

No. 3. Comparison of water rates required to drive a 31,000-ton battleship with direct-connected turbine machinery and with turbine electric machinery, the water rates being referred

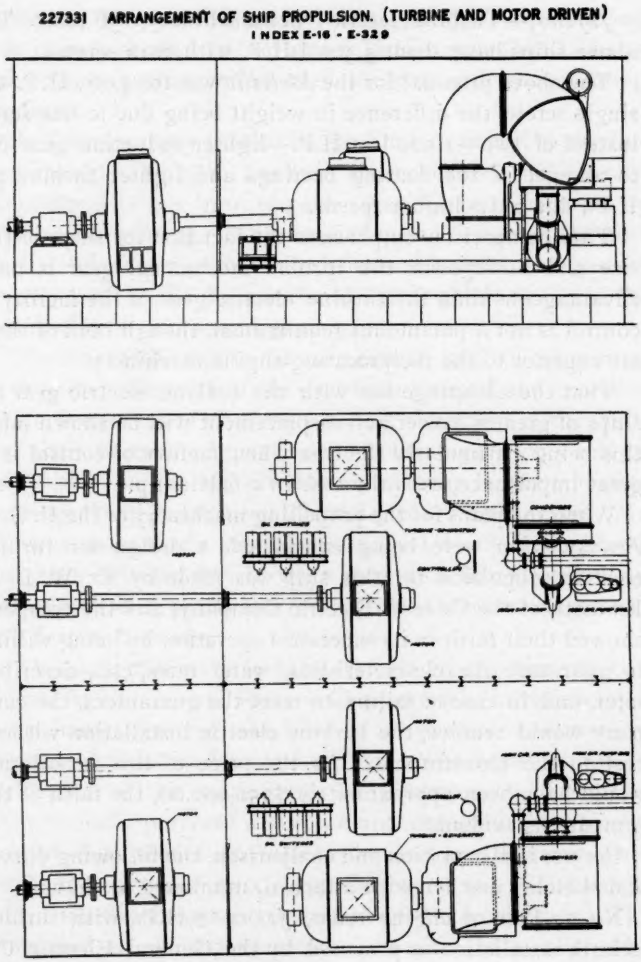
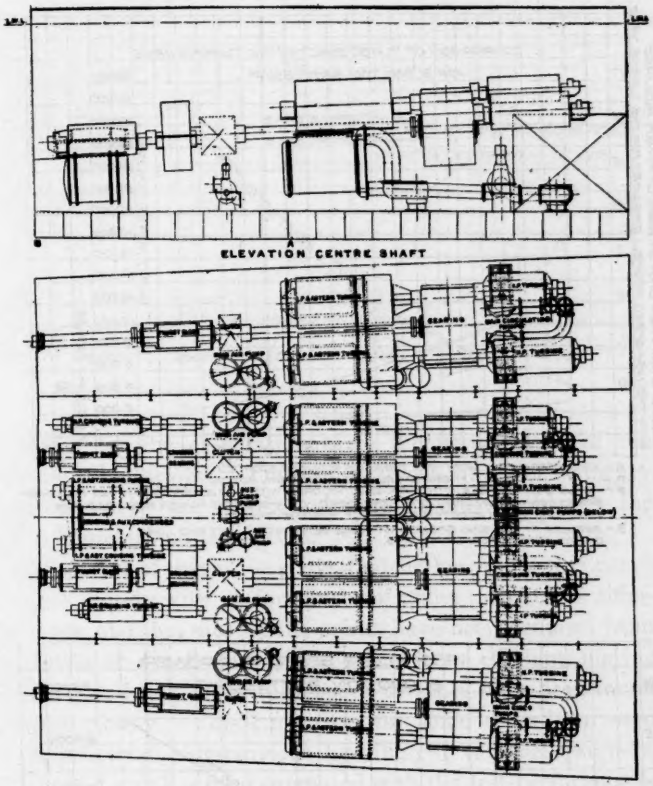


FIG. 1.

to the power, 31,700, required for the propellers of higher speed. The curves show the relation between the amount of steam required per knot at the different speeds, these calculations being made by Mr. W. L. R. Emmett.



227332 GEARED TURBINE MACHINERY FOR BATTLESHIP WITH SEPARATE CRUISING INSTALLATION.
INDEX E-16 - E-329

FIG. 2.

No. 4. Shows the relation of powers required to drive the ship at 21 knots with different propeller speeds and also the diameter of propeller for different r.p.m. at 21 knots.

No. 5. Is a curve published in London "Engineering" of December 29, 1911, in connection with a series of articles on the subject of "The Steam Turbine." This curve is the

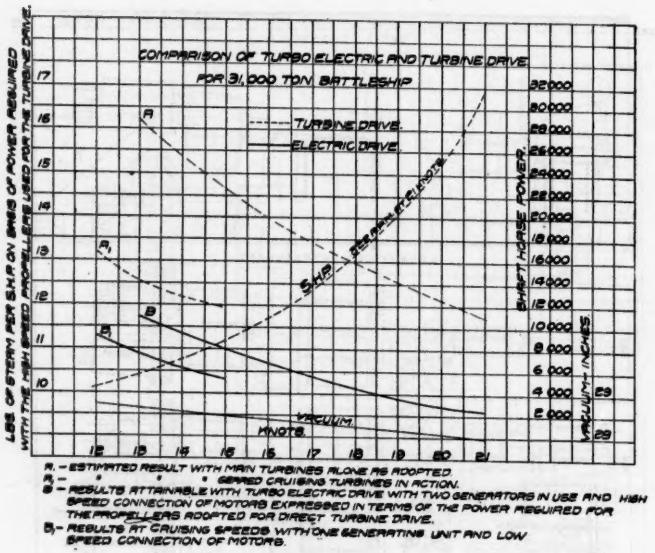

COMPARISON OF TURBO ELECTRIC AND TURBINE DRIVE.
FOR 31,000 TON BATTLESHIP
TURBINE DRIVE.
ELECTRIC DRIVE.
SHIP RESISTANCE
SHAFT HORSE POWER.
VACUUM INCHES
KNOTS.
VACUUM.
LBS. OF STEAM PER S.H.P. ON BASIS OF POWER REQUIRED WITH THE HIGH SPEED PROPELLERS USED FOR THE TURBINE DRIVE.
A. – ESTIMATED RESULT WITH MAIN TURBINES ALONE AS ADOPTED.
B. – " " " GEARED CRUISING TURBINES IN ACTION.
C. – RESULTS ATTAINABLE WITH TURBO ELECTRIC DRIVE WITH TWO GENERATORS IN USE AND HIGH SPEED CONNECTION OF MOTORS EXPRESSED IN TERMS OF THE POWER REQUIRED FOR THE PROPELLERS ADOPTED FOR DIRECT TURBINE DRIVE.
D. – RESULTS AT CRUISING SPEEDS WITH ONE GENERATING UNIT AND LOW SPEED CONNECTION OF MOTORS.

FIG. 3.

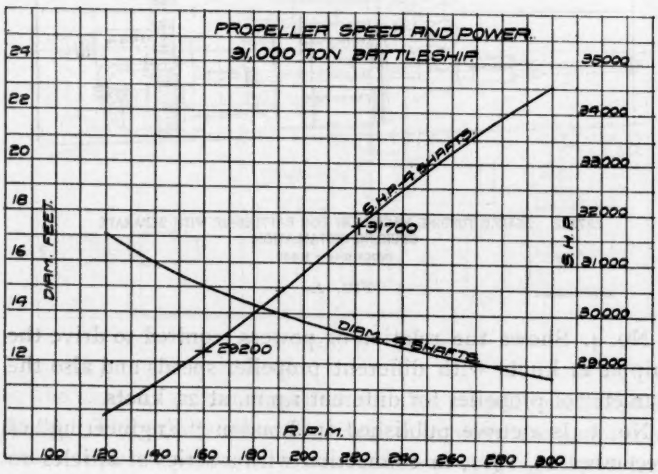

PROPELLER SPEED AND POWER.
31,000 TON BATTLESHIP
DIAM. FEET.
S.H.P. 4 SHAFTS
31700
29200
DIAM. 4 SHAFTS
R.P.M.
S.H.P.

FIG. 4.

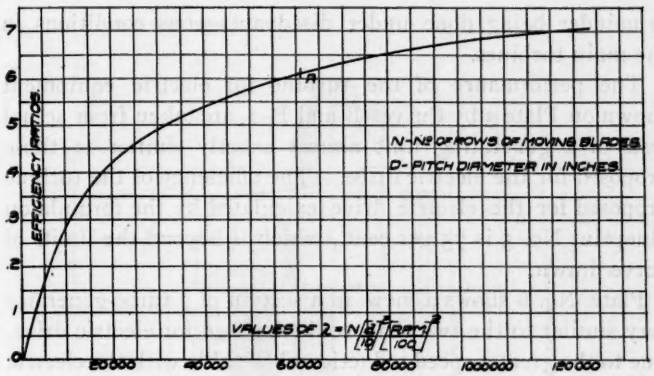


FIG. 5.

authority for the calculation as to the performance of the steam-turbine design. This curve shows limits of efficiency as governed by the number of rows of moving blades, the pitch diameter and the speeds.

The author of this curve states that he has found this curve to agree closely with performances of many turbines of different types, and that most of the points have been deduced from the trials of a set of very large and very efficient marine turbines, and that many high-speed turbines have been found to agree closely. This curve has, for some time, been used for approximate comparisons by different turbine designers, and in that way has been compared with the test performances of a large number of the best turbines of recent design, and in all of these only one or two came slightly above the curve.

The maximum possible efficiency of direct-connected turbines with cruising turbines having reduction gear with certain assumed numbers of blades and diameters should be indicated by the point marked "A" in the curve, and this value has been used in working Curve "A" for high speeds on blueprint No. 3. The curve marked "A_1", for cruising conditions, is obtained in a different way, but it is believed it shows even better rates than can be obtained with a design in which the geared turbines perform only half the work required, the

remainder being done under disadvantageous conditions in the main turbines.

The performance of the turbine for electric equipment shown on Plate 3 by Curves B and B–1, are taken from actual tests of a generating unit almost exactly similar to those proposed for the electric drive. The efficiency of the turbine proposed for the electric drive calculated by the formula on blueprint No. 5 is 75 per cent., which is beyond the limits of curve drawn.

Plate No. 6 shows a view in a section of a turbo-generator very similar to the two that would be used for electric drive. Due to the greater speed reduction obtainable with the electric drive, it will be noted from blueprint No. 4, that 160 r.p.m. would be used instead of 222, the diameter of propeller would be 15 feet instead of 13 feet, S.H.P. 29,200 instead of 31,700, due to more efficient propellers. Using the data from the above-mentioned curves, the following table shows the weights of the two equipments for a 31,000-ton battleship.

.....	R.P.M. 21 knots.	S.H.P. required, 21 knots.	Pounds steam per hour turbines alone, 21 knots.	Pounds steam per hour turbines alone, 15 knots.	Weight driving machinery, in tons.
Turbine drive with geared turbine for low speeds.....	222	31,700	374,000	106,000	749
Turbine-electric drive	160	29,200	305,000	91,000	598

The individual weights being as follows for electric machinery:

One motor, 164,000 pounds; outside diameter, 172 inches.

One turbo-generator, complete, 320,000 pounds; the generator being 200,000 pounds and the turbine being 120,000 pounds.

With reasonable allowances for steam required outside of

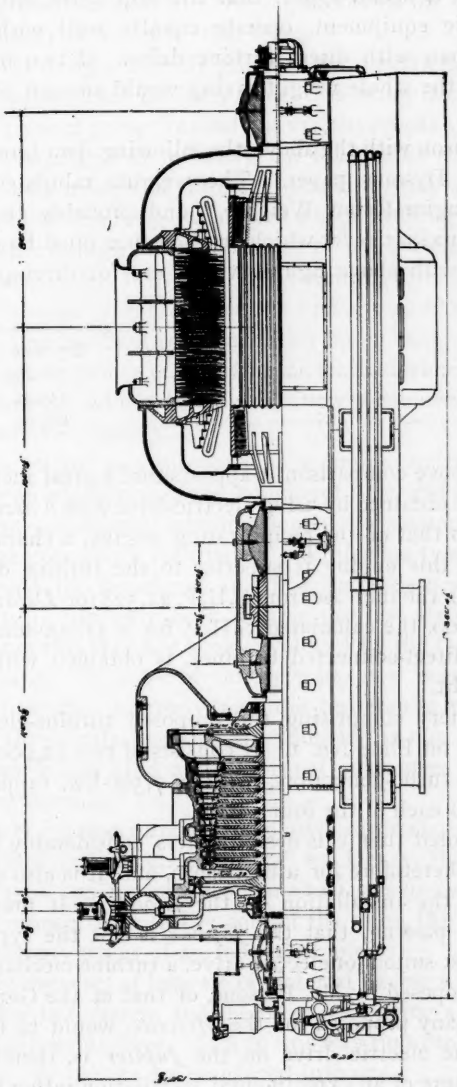

224985 ASSEMBLY CROSS SECTION OF 10000 KW. 1500 R.P.M. HORIZONTAL STEAM TURBINE
INDEX E-16

FIG. 6.

main turbines, it would appear that the ship could, with the turbine-electric equipment, operate equally well with two boilers less than with direct turbine drive. If two boilers were omitted the whole weight saving would amount to 266 tons.

For comparison with the above, the following data is quoted from Captain Dyson's paper. The weights tabulated are given as "Engine-Room Weights," and probably include engine-room auxiliaries for which an allowance must be made in comparing with above figures which, are for driving machinery:

	Engine-room weights, dry tons.
Delaware	728.26
North Dakota	731.23
Utah	864.69

From the above comparison it appears that a great increase in H.P. may be obtained by using electric drive with a *decrease* in weight from that of the reciprocating engine, a characteristic in which this engine is superior to the turbine direct connected. As the increase from S.H.P. 21,528 for *Delaware* to S.H.P. 31,700, the calculated S.H.P. for a 31,000-ton battleship with direct-connected turbines, is obtained with increase in weight.

The machinery comprising the proposed turbine-electric drive is shown on Plate No. 1. It consists of two 12,000-kw. (approximate) turbo-generators, with a 7,500-kw. (approximate) motor on each of the four shafts.

It will be noted that this design differs considerably from that proposed heretofore for a battleship, and it is also quite different from the installation on the *Jupiter*. It may be noted here, in passing, that the *Jupiter* is not the type of ship that is best suited for electric drive, a turbine mechanical gear of type proposed by Mr. Parsons, or that of the General Electric Company proposed for the *Melville*, would be more desirable. The electric drive on the *Jupiter* is, therefore, more in the nature of an experimental installation rather than

being one that best fills the requirements for the propelling machinery of a ship of that type.

In the design formerly proposed for a battleship two motors were to be used on each shaft, this being necessary to meet conditions of going "ahead" at various speeds and at stopping and "backing," as to handle the load under these two conditions two motors of different characteristics were necessary, one of low reversing torque and a high running efficiency, and the other of high reversing torque by using external resistance to start under full load, the "running" motor was of the squirrel-cage type, the other was a polar-wound motor with slip rings and external resistance, this latter being used to absorb the high current when starting under load when a high torque is required, which is the condition when the ship is being maneuvered, backed, etc.

The motor now proposed is a double squirrel-cage motor, being an adaptation of the Boucherot type, and it is one having a most satisfactory combination of the characteristics of the two motors above mentioned. While this type of motor was designed by Boucherot in 1894 and 1895 with successful results, it has only been during the last six months that a motor of this type has been developed by the General Electric Company. A motor of this type has now been designed and tested by this company, and the test results agree so closely with the calculations that the company is now ready to build motors of this kind with the usual guarantees covering satisfactory service.

As the name implies, the double squirrel-cage motor (well described in "Electric Motors" by Henry M. Hobart, pages 325–336), has for its secondary two sets (outer and inner) of bars concentric with the core of the rotor, the primary being an ordinary stator of an induction motor.

The outer set of bars are of material having a high resistance and low inductance, and the inner set having a low resistance and high inductance. It is in this way that the characteristics of the two motors are combined into one.

The action is as follows: At starting, the current induced

into the high resistance (outer) bars exerts a high starting torque, a necessary requirement for backing the ship. As the motor comes up to synchronous speed the inner bars of low resistance carry the larger part of the current; the losses are small and the efficiency high. The application of this method, even in a small degree, makes it possible for the generator and the motor to pull into synchronism in a very brief period, after which full torque of the turbine for reversal is available, or, if desirable, provision can be made for ample torque without approaching synchronism.

This type of motor exactly fulfills the requirements for ship propulsion where such wide variation of loads, speeds and operating conditions are found. This motor also is adaptable to pole changing in the desired ratio, which is accomplished by a simple group of pole-changing switches in the stator circuits.

Print No. 7 shows the torque curve of this type of motor

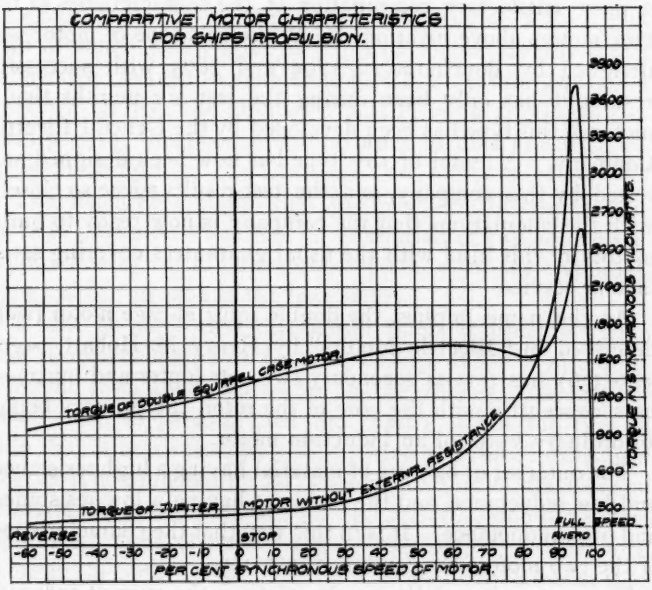

COMPARATIVE MOTOR CHARACTERISTICS FOR SHIPS PROPULSION.
TORQUE OF DOUBLE SQUIRREL CAGE MOTOR.
TORQUE OF JUPITER MOTOR WITHOUT EXTERNAL RESISTANCE
TORQUE IN SYNCHRONOUS KILOWATTS
REVERSE
STOP
FULL SPEED AHEAD
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
PER CENT SYNCHRONOUS SPEED OF MOTOR.

FIG. 7.

and also the torque curve of the *Jupiter's* motor when the external resistance is short-circuited, which is the "running" condition of the latter; with the resistance in circuit, a high "reversing" torque is obtained. The features of design, as mentioned above, of the double squirrel-cage motor allow a high torque under all conditions without the necessity of external resistance.

It is due to the fact that relative speeds of the motor and generator depend upon the relation between their poles that the electric units allow such a large reduction of speed between the turbine and propeller, thus permitting the turbine to run at its efficient speed, which is necessarily high, and the propeller to run at its efficient speed, which is necessarily low.

The speed of the motor is to the speed of the generator in an inverse ratio of their respective poles. On the *Jupiter*, for instance, the generator has two poles and the motors have 36, the speed reduction is 18 to 1. It is due largely to this fact that electric propulsion does not lend itself so readily to ships of small horsepower, as the size of the motors mechanically limits the number of poles, and therefore the speed reduction is more limited than in ships of large horsepower where large motors are used.

It seems that about 5,000 or 6,000 S.H.P. is about the low limit for electric propulsion; below these powers mechanical reduction gearing is generally more efficient and desirable unless facility of control is paramount. Each case must, therefore, be decided in accordance with requirements.

The poles of an induction motor depend upon its windings, and the windings can be so connected to a pole-changing switch or controller that the number of poles may be changed in a certain definite ratio as desired. This permits the ratio between the poles of the generator and of the motors to be varied to produce the most economical operation at the high and at the low speeds of the ship, and it is in this way that the economical rates as shown on Curve B and blueprint No. 3 are obtained.

For the electric drive shown on Plate No. 1, the turbine and generator would have a speed of about 1,900 r.p.m.; the generator would have been a bi-polar and the motor would have had 24 poles for speeds above 15 knots, and 36 poles below 15 knots, allowing speed reduction of 12 to 1 for high speed of ship and 18 to 1 for cruising speed. Minor variation in speed is obtained by varying speed of turbine by governor control.

The electric drive permits great facility of control either from the bridge or any other point, such as conning tower or any fire-control station, and in this point easily excels the reciprocating engine, the turbine direct-connected, or the turbine mechanical gear. The propeller may be started ahead, stopped, or run astern by turning the handles of a controller, which can also be used to control the turbine speed as desired. The turbine governor automatically regulates the speed of turbine when load is varied on the motor.

An advantageous point in this equipment is that, as the speed of the motor is synchronous with the generator, the propellers cannot race when the ship pitches them out of the water, the speed of the generator being controlled by a particular design of governor on the turbine. This not only saves the wear on the machinery, but saves the loss caused by the inefficient speed of the propeller when racing, which it is believed would make quite a difference in the fuel per knot in heavy weather.

By using the above-mentioned motor a starting torque of 100 per cent. full-load running torque may be obtained. This allows as high backing power as the design of propeller will permit, and in this way equals the reciprocating engine and far excels the turbine mechanical-reduction gear. The lack of sufficient backing power has been a very unsatisfactory point in our turbine ships. From Captain Dyson's paper the following is tabulated:

	Backing power in per cent. of ahead power.
U S. S. *Delaware*	87.5 per cent.
U S. S. *Utah*	35.7 per cent.

From trials, the *Delaware* steaming at 21 knots, and the *Utah* at 20 knots, the time taken to bring the vessels dead in the water were, for the *Delaware*, 1 minute, 52 seconds; the *Utah*, 4 minutes, 44 seconds. For reasons above mentioned the "electric" battleship would be equal to or superior to the reciprocating-engine ship in this regard.

From data tabulated in the JOURNAL OF THE SOCIETY OF NAVAL ENGINEERS, February, 1913, pages 83 and 84, it is seen that the *Delaware* at a speed of 21.56 knots per hour required as follows:

Total water, all purposes, per hour, pounds	422,931
Pounds of coal per knot per hour	2,502
Total of coal, 24 hours, tons	578

This data agrees closely with the data obtained from contractor's trials, when the pounds of coal per knot per hour were 2,640.

Using the above data it is found that the *Delaware* had a boiler evaporating factor of 9.5 pounds of water per pound of coal.

Using the factor of 9.5 pounds water per pound of coal, and taking the guaranteed water rate of 9.6 pounds water per S.H.P. for the electric battleship, and assuming 60,000 pounds water per hour for auxiliaries, which, according to data obtained from the *Florida* and *Utah*, is a fair figure, we find as follows, for speed of 21 knots:

Pounds water, main engines	= S.H.P. × water rate,
	= 31,700 × 9.6 per hour,
	= 304,000 pounds.
Pounds water for auxiliaries	= 60,000 pounds per hour.
Total water all purposes	364,000 pounds per hour.
Pounds of coal per hour (using 1 pound coal × 9.5 pounds water)	38,300
Pounds of coal per knot per hour	1,800
Tons of coal per day (24 hours)	410

From the performance curves of the *Delaware* on contract trials it is found she burned 1.85 pounds of coal per I.H.P. per hour at 21 knots. Taking this figure, and using the

same water consumption for auxiliary purposes as that tabulated for 21.56 knots, we get a total expenditure of 518 tons of coal per day.

From the performance curve as calculated by Mr. Emmett for the straight turbine ship, and allowing auxiliary rate same as electric battleship, we get a total expenditure of 503 tons per day.

At 12 knots, using tabulated results from *Delaware* and estimated performances of the turbine ship and the electric ship, we get for total expenditure per day: *Delaware*, 110 tons coal; turbine ship, 104 tons; and electric ship, 87.5 tons. In this calculation the auxiliary water consumption for the turbine battleship was approximated from performances of the *Florida* and *Wyoming*.

The water consumption of the electric battleship for auxiliaries at 12 knots is estimated to be about 25,000 pounds per hour, a little more than that of the *Delaware*, but considerably less than that of the turbine ship, this being due to using only one turbo-generator for the four shaft motors, thus allowing one air pump and circulating pump to be shut down and thereby saving the expense of their operation. It is probable that the water rate for auxiliaries may be even less than that for the *Delaware* as the auxiliaries in operation will not only be less in number, but they will be operating at nearer full load, which is better than running a larger number of machines at a small load.

This principle predominates throughout the turbo-electric installation that the machines in operation are so adjusted that they are generally operating at very near their full load, which, of course, is a more economical condition than where a big machine is required to run at greatly reduced load, such as is the case in the turbine ships at cruising speeds, when the cruising turbine with reduction gear is used and when the steam from this turbine is exhausted into the big H.P. ahead turbine, which will then operate with a load and steam pressure so greatly reduced from those for which designed, it will probably not be efficient and economical. Using the above data, the following comparison is tabulated:

At 21 Knots.

Ship.	Pounds coal per knot per hour.	Tons of coal per 24 hours.
Delaware	2,300	518
Turbine battleship	2,249	503
Electric battleship	1,820	410

At 12 Knots.

Delaware	855	110
Turbine battleship	808	104
Electric battleship	650	87.5

To substantiate the above estimates in regard to the turbine battleship the following data in regard to the French battleship *Jean Bart* is quoted from the "Naval Institute," of September, 1913, pages 1325–6–7. The *Jean Bart* has the following characteristics:

Length on water line, feet and inches	541-4
Beam, feet and inches	88-6
Maximum draught, feet and inches	29-6
Normal displacement, tons	23,467
Designed horsepower	28,000
Designed speed, knots	21
Type of machinery	Parsons turbines, direct-connected.

The turbine ship above referred to has the following characteristics:

Displacement, tons	31,000
Designed S.H.P	31,700
Speed, knots	21
Type of machinery	Curtis turbines, direct-connected, with mechanical reduction gear for cruising turbine.

From the characteristics it is safe to estimate that the E.H.P. of the two ships is about the same. The following are results of official trials of the *Jean Bart:*

Date, April 29, 1913.	
Trial	Ten hours, full speed.
Average speed, knots	21.09
Coal per mile, pounds	2,449
Tons coal per day	553.2
Date, May 15, 1913.	
Trial	Fuel consumption, cruising speed.
Average speed, knots	12.81
Coal per mile (actual), pounds	937
Tons of coal per day	128

It is stated that the machinery of the *Jean Bart* went through the steaming tests without a hitch, and that for three hours she averaged a speed of 22.04 knots with a run on measured mile 22.63 knots. From this it is seen that her machinery must be highly efficient and satisfactory within the limits of its design.

These results show such an enormous difference in favor of the electric drive that they will undoubtedly be seriously questioned, but the General Electric Company stand ready to guarantee the results within five per cent., and to support the guarantee, as above mentioned, by any reasonable sum of money, and by agreeing to remove the machinery if it does not fulfill the guaranteed performances. As the sum of money is so large, the company do not take this action without being sure of their ground.

The reason that they can be so sure of guaranteed results is that the machinery has all been built, tested and tried out in various conditions on shore, so that the efficiencies and methods of control are accurately determined. The only new engineering involved in electric propulsion for a battleship being that of applying well-tried machinery to the conditions on board ship, and this point should be kept well in mind when considering the proposition, and particularly when comparing the electric installation with the mechanical reduction gear, as the latter is still not in a completely developed state *as a machine* for high powers and speeds, although it has so far proven most satisfactory under certain conditions. But even if the mechanical gear becomes entirely satisfactory for any power and speed, the extra turbines will always be necessary for running astern.

By referring to Plate No. 2, attached, we can see where a following of the mechanical gear will lead, for high powers. This is the plan outlined by Sir Charles Parsons. It contains 22 ahead turbines, 10 astern turbines and 6 sets of mechanical gearing. The sketch does not show the piping, but the mass of it may be imagined. Installations for a battleship of 40,000 H.P. with four shafts, 200 r.p.m.; for a cruiser, 30,000

H.P., 300 r.p.m., and for a destroyer of 20,000 H.P. at 440 r.p.m. were also outlined by Mr. Parsons, all being along the same general plan as shown on Plate No. 2, for battleship of 60,000 H.P. It will be noted that the r.p.m. mentioned for the propellers are much too high for the best efficiency.

The above figures show that the *Delaware* will compare about as favorably with the turbine direct-connected battleship having cruising turbines with reduction gears as she did with the *Utah* and *Florida*, as shown by Captain Dyson.

The *Delaware* was completed in 1909, and it is interesting to note that, if the above calculations are correct, the turbine direct-connected ships, even when fitted with cruising turbines having mechanical reduction gears, are not the equal of a reciprocating-engine ship, considering all the military and economical characteristics desired in a battleship. The trials of the *Texas*, having reciprocating engines, further confirm this.

If the turbine ship mentioned be supplied with reduction gear for each turbine in the manner outlined by Sir Charles Parsons, the steam economy could not equal the electric drive proposed, unless the same turbine and propeller speeds were accomplished. To do this the mechanical gear would have to be built, tested and tried out; in other words, it would be a new design throughout. But even if the same economy were obtained, the difference in weight, complication and, what is of most importance, the maneuvering and backing performances of the ship, would be so greatly in favor of the electric drive that it completely excels the mechanical design.

When considering the care and upkeep of the machinery, it is evident that the electric installation would be superior to all others, because there are no small parts to get out of order; the motion being entirely rotary, the bearings would give no trouble, particularly with forced lubrication; and the turbines being only two in number and therefore very large and of durable construction, the troubles mentiond by Captain Dyson under this heading for turbines direct-connected would largely disappear.

There would be no more reason to expect a large amount of work under care and upkeep of the electric units than is found on machines of this size in control-station power plants, which is practically nothing.

Returning to comparison of direct-connected turbines with other types of propulsion, it was shown by comparison with the *Delaware* that for a battleship the reciprocating engine is even superior to the direct turbine drive. The difficulty of applying the steam turbine to ship propulsion was emphasized in a report made by Rear Admiral Melville and Mr. John H. Macalpine, in May, 1904, and published by Mr. Geo. Westinghouse, 1909, in his book, "Broadening of the Field of the Marine Steam Turbine; the Problem and its Solution." This report was made after an exhaustive investigation of the development of the steam turbine in England and in Europe. In this report the lack of superiority in economy of the turbine over the reciprocating engine, as well as the inferior maneuvering and backing power, was pointed out. Having in mind the latter, it was stated that the Marine-Baumeister, Gustav Berling, of the German Navy, remarked that, "he hoped all the ships of the enemies of Germany would have turbines."

Admiral Oram expressed the opinion "that the turbine would never be suitable for warships on account of the inefficiency at low powers." Sir Charles Parsons recognized the difficulties, and it is interesting to note the enthusiasm with which he has jumped at the mechanical reduction gear.

In concluding the report, it is stated that, "if one could devise a means of reconciling, in a practical manner, the necessary high speed of revolution of the turbine with the comparatively low rate of revolution required by an efficient propeller, the problem would be solved and the turbine would practically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of genius."

The "solution of this problem" is now undoubtedly accomplished in the mechanical reduction gearing and in the electric-machinery method. Which one to choose depends, as stated

above, on the kind of ship and her desired performances, so that each case must be carefully studied, neither form of speed reduction being regarded as a "sure cure" for all cases.

A study of the requirements of a battleship's propelling machinery shows that the turbine-electric propulsion meets the demands in really a wonderful way; in fact, it is in this type of ship that the electric drive finds its most attractive application, although it is also probable that the development of the submarine cruiser will offer a large field for its use.

Returning to the requirements as given by Captain Dyson it is believed that the above data and comparisons show conclusively that for a battleship the turbine electric-propelling machinery completely outclasses not only the reciprocating engine, but all other types of machinery now developed for the purpose, the points of superiority being as follows:

(1) Economy at moderate and low speeds, hence great cruising radius.

(2) Economy at maximum speed, hence ability to run at highest speeds without exhausting the fuel supply or fireroom force if coal is used.

(3) Great reliability when driven at maximum speed.

(4) Facility of control—high backing power, efficient propellers.

(5) Less weight of machinery and space occupied by it.

(6) Less boiler weight.

(7) Work necessary for care and upkeep, allowing greater radius of duty.

(8) Lack of racing of propellers, hence greater ability to steam at high speeds in a heavy sea.

The last item (No. 8) is accounted for by the fact that the motors are of the synchronous type, and always run at a speed which bears a definite relation to the speed of the generator, which, being direct-connected to the turbine, runs at the turbine speed. As the load comes off the propeller, due to the ship's pitching, the turbine is automatically slowed down by its governor, the latter being of the well-known dependable type used with all turbine installations with certain particular features.

After an earnest consideration of all the engineering features involved in battleship propulsion, the writer has failed to find a single one against the turbine electric drive for this purpose; in fact, all the desirable ones are in its favor, and show the wisdom of the Bureau of Steam Engineering and the Navy Department in making the experiment on the *Jupiter*.

The question now arises, "Are there any reasons why the electric drive shall not be placed on one of our warships of the first class without further delay?" The writer has failed to find any.

It may be feared that great danger from short-circuits, electric burn-outs, etc., may exist, that the electric units might "burn out and blow up." Years of experience on shore with electric apparatus of similar character, power and voltage have shown an almost complete immunity from insulation or short-circuit trouble. In fact, the probability of trouble of this nature on board ship would be less than on shore, as in the ship installation only the amount of electricity required is generated, this being automatically regulated by the turbine governor as the load varies, and there are no possibilities of overload and resulting burn-outs as might occur on shore. Also, the circuits are short and direct, and thus avoid all vibrating strains on the insulation, which is frequently the chief cause of break-down on long circuits carrying high voltage.

The dangers to result from water entering the engine room are no greater than in one with any turbine installation without this machinery; they are less, in fact, as short-circuits can be entirely guarded against and, due to the fact that the four motors can be operated by one turbo-generator, the ship could continue to run at 80 per cent. of her designed speed as long as one of the two turbo-generators rooms were free of excessive water. The windings of these motors are heavily covered by a completely water-proof installation, and if the terminals were properly covered, they could run under water indefinitely. It must be remembered that A. C. current machinery is not subject to the same effects from water as

those using D. C. current. As all the circuits of an induction motor are stationary, it is easy to apply waterproof insulation.

The writer has seen an induction motor (squirrel-cage type) run without difficulty completely submerged in water, and this with no special precautions except to see that the connections were insulated. Of course, the motor is overloaded in this condition, due to the mechanical action of the armature burning against the resistance of the water; but as the water serves as a good cooling agent, the motor can carry a considerable overload in this way without dangerous heating.

Therefore, in case of water entering the engine room, nothing would burn out or blow up. The motors would continue to run until the overload due to the resistance of the water to the revolutions of the motor and the leakage of current became too great for the generator to pull. The point to be understood here is that the electric units would not be the first to be adversely affected by the presence of water. The steam turbine would be in more danger from water than the electric machines, as, if the turbines became partly submerged by water, there would be so much condensation of steam that the turbine could not run. The engine-room steam auxiliary machinery would also be more seriously affected than the motors. So that the presence of the electric machinery in the engine rooms does not cause a more unsatisfactory condition to exist in case the engine room is flooded with water than exists with other types of propelling machinery; in fact, an advantage is gained with the electric installation, because of the fact that the four propellers can be driven by one turbo-generator. Also, the water can be more easily isolated, due to the division of the engine-room space into four watertight compartments which are more independent of each other as shown than they are with other types of machinery.

Reference to Plate No. 2 will show the machinery placed in four watertight compartments so that the flooded compartment can be easily isolated and the ship could continue to run until *both* turbo-generator rooms were flooded.

The danger of personnel would be practically nothing, as

the switches would all be enclosed in an oil bath and the conductors heavily insulated, so that a man would have to almost deliberately set about getting an electric shock by placing his hands on the bars behind the switchboard, and even these could be well protected against such foolish action. There would be no mass of complicated wiring; on the other hand, the conductors would be short, direct and heavily insulated.

With the electric drive the revolutions of the propellers can be accurately regulated from the bridge, and the ship sent ahead, stopped or backed, as desired; provision for all these operations would, of course, be made in the engine room also. But all the trouble and uncertainty of communicating quickly between the bridge and engine room would be avoided. The troubles of voice-tube and telephone communication between bridge and engine room are well known. This was illustrated on one ship recently, when the captain asked the engine room by voice tube if the senior engineer officer were in the engine room; the reply was, "Making 73 (r.p.m.), Sor!"

One thing against the adoption of the electric drive for battleships is that it "sounds too good," but when it is remembered that a thoroughly reliable company is standing ready to put up any sum of "good, hard money," this idea should be forgotten.

Another idea is that if the electric scheme is so good, why do not the merchant ships builders jump at it? The answer is, as pointed out above, the advantage to be gained in ships of constant speed and where maneuvering and control features are not paramount, is not so great as in a battleship.

Also, a largely-influencing factor in this matter is that the shipbuilding companies are not equipped to build in their own shops the electric machinery, and it is therefore against their interest to advocate a battleship having the electric machinery, as it would cause a loss of about a quarter of a million dollars worth of work from the shop of the shipbuilder having the contract.

The opinion has been expressed (see London "Engineer-

ing," December, 1911) that although everything seems to indicate the success of electric propulsion for a battleship, and that it is in a battleship that this method of propulsion finds its best adaptation, yet this very fact prevents a practical demonstration of the design, as it would not be wise to use one of the Navy's capital fighting ships for such an experiment.

It has also been stated that although the General Electric Company would remove the machinery, in case of not fulfilling the guarantees, without money loss to the Government, yet the delay in such a contingency in the final completion of the ship would be too great to warrant taking the chance, even though it might be a remote one. All this, it seems to the writer, depends entirely upon the engineering facts in the matter, as shown by a careful analysis, not a general opinion. If the engineering experience with the machinery to be installed and the data collected, therefore, show conclusively that the machinery will operate as intended, then its application to the purpose of battleship propulsion partakes very little of the nature of an experiment, although it would be something new and different from what has heretofore been done; but new departures in engineering of greater magnitude and with less chance of success are being undertaken all the time, and it is in this way real progress is made.

In this connection it should be remembered that there is really more chance being taken with the large marine turbines direct-connected than with the turbine-electric equipment, because, in the former case, a new and untried machine has to be constructed, which, due to the small number in use, has not had opportunity to be standardized; while with the turbine-electric equipment a machine would be used which has been fully developed in its service in land installations. This is evidenced by the well-known difficulties encountered on board ships with the turbine direct-connected machinery as mentioned in Captain Dyson's paper, while little is heard of such troubles in shore-power stations.

The nature of the electric design is such that the entire

propelling machinery could be tested out under all operating conditions in the factory before being placed in the ship. As the General Electric Company would guarantee to build and test the machinery within a year after the receipt of order for it, all defects could be remedied and the machinery would be ready long before the ship would be ready for its installation, and, in the very remote event of the machinery not fulfilling the guarantees on test, machinery of another design could be built for this ship without delaying her date of completion an excessive amount. The chance of any delay of this sort, however, is so small, and the advantages to be gained are so great, that the taking of what chance of this nature that may be thought to exist would be more than warranted, because the engineering facts and experience already obtained from operation of this type of machinery show that it would operate in the ship as intended.

It is believed that the above comparisons show that, when considering the two main characteristics of the propelling machinery of a battleship—namely, those military and those economical—the reciprocating engine as now installed is and will continue to be superior to the turbine direct-connected, even when reduction gears are used with the cruising turbines, and that, on the other hand, the turbine-electric machinery is greatly superior to the reciprocating engine, and that this superiority is so great that its adoption will represent a distinct epoch in the engineering military efficiency of the Navy.

It is desired to again emphasize the importance of the lack of "racing" of the propellers in a heavy sea when driven by the electric machinery. This would enable the ship to run at top speed in any sea, and this fact alone might be the deciding factor in a naval campaign.

Since the above article was written the *Jupiter* has been finished and accepted, her performances exceeding the requirements, and a year's service has demonstrated the reliability and practicability of her electric machinery.

MOTOR-CYLINDER LUBRICATION.

A STUDY OF THE CONDITIONS UNDER WHICH THE LUBRICATION TAKES PLACE, AND OF THE CHARACTERISTICS OF MOTOR-CYLINDER OILS THAT DETERMINE THEIR SUITABILITY FOR THESE CONDITIONS.

By Lieutenant G. S. Bryan, U. S. Navy, Member.

If an internal-combustion engine, using a certain brand of lubricating oil, runs indefinitely without giving trouble of any kind, we can feel certain of two things; first, that it is a well designed engine, and second, that it is using a good lubricating oil. Otherwise, trouble would occur.

If trouble does occur in an engine, however, we are confronted with several possibilities:

1st. The engine and lubrication system may be poorly designed.

2d. The oil may be poorly refined.

3d. The oil may not be supplied to the cylinders in the right amount.

4th. The oil may be of good quality, but may not be suited to that particular engine.

Trouble due to the first case is exceptional. That due to the second case is more frequent, perhaps, but is also exceptional among well-known brands of oil. That under the third case depends sometimes on the design of the engine, but more often on the lack of care exercised in maintaining the proper oil level in the crank case. The remedy for both of these faults is obvious. Trouble encountered under this head may well depend, however, on the fourth case, in that it is necessary to use an oil that is *suitable* as well as of good quality, or the correct amount will not be supplied the cylinders.

We can assume that most of the engines on the market are correctly designed. From the fact that most of the different varieties of oils on the market work satisfactorily in some engines, we can also safely assume that they are good oils when properly used in the right place. A consideration of the properties of motor-cylinder oils, and an analysis of the conditions under which they lubricate, lead us to the belief that a large majority of the complaints about motor-cylinder oils can be accounted for as due to ignorance regarding the principles governing their use.

Most gasoline motors have their cylinders lubricated by the splash system, the bearings being sometimes lubricated by forced feed. In some cases the cylinders are also lubricated by forced feed, the oil being injected through small holes in the side of the cylinder that are continually covered by the piston. The general principles governing cylinder lubrication, however, apply to both systems.

In the splash system on four-cycle motors the reserve oil is contained in the crank case and each cylinder is lubricated by the splash of its own crank. A small dipper on the end of the connecting rod dips into a trough of oil when the crank is at its lowest point, and with the upward stroke of the crank throws the adhering oil violently against the cylinder walls, splashing it in every direction. This oil is then spread evenly on the cylinder walls by the piston as it slides up and down. Every up-stroke of the crank thus gives a new supply of oil, and every up-stroke of the piston smears some of this oil on the upper part of the cylinder where the combustion takes place.

The operation in a four-cycle motor then is as follows:

Suction stroke.—On the previous up-stroke of the piston oil was spread on the cylinder walls, and this furnishes lubrication as the piston descends on the suction stroke. At the bottom of the stroke the dipper dips into the oil.

Compression stroke.—The film that has just lubricated the piston on the suction stroke will not be affected by the cool gases entering from the carburetor, and will be left intact to

lubricate on the compression stroke. As the piston goes upward it smears a fresh film on the walls. A new supply of oil is also splashed on the lower part of the cylinder by the upward throw of the crank.

Explosion stroke.—The film smeared on the walls on the compression stroke is also sufficient to lubricate the piston on the down stroke. The combustion space on this stroke is exposed to a very high temperature, but the flame only comes into contact with the oil film after the latter has performed its allotted function of lubricating the piston; therefore no difficulty should be encountered. At the bottom of the stroke the dipper again dips into the oil.

Exhaust stroke.—This is the part of the cycle where the most difficulty is encountered with the lubrication. The oil film on the upper part of the cylinder walls has just been exposed to the very high temperature of the ignited gases, and has certainly been damaged to some extent. It still possesses some lubricating value, however, and also the piston itself is now covered with a film which it is about to smear on the walls as it moves upward. The combination of these two factors should be sufficient for the lubrication of this stroke. If trouble is encountered due to faulty lubrication, however, it will show principally on this stroke.

In the two-cycle type conditions are more severe. The oil film is here exposed to the temperature of the explosion every revolution instead of every other revolution as in the four-cycle type. To offset this, however, we have a lower compression and generally slower piston speed. When this is taken into consideration the problem does not appear to be so difficult, and experience has shown that this type can be lubricated efficiently without any particular difficulty.

The three essential requirements of a good motor-cylinder oil are:

1st. It must lubricate the piston efficiently at the temperatures encountered in the cylinder.

2d. It must give a good seal to the piston and rings, keeping them tight and preventing leakage of the oil and condensed gasoline past them.

3d. It must burn without forming carbon deposits *in the cylinder* when an excess of the oil gets into the combustion space.

The first requirement is a general one. If we examine closely into the action of the film of oil we shall see that it is subjected to widely different conditions at different depths. The lubricating value of an oil is due to the fact that when the surfaces of the cylinder and piston are separated by a film of oil the friction of these two metal surfaces is eliminated, and the friction that remains is only that occasioned by the sliding action of the molecules of oil past each other. In other words, it is the same as if two layers of oil are sliding past each other, and the friction that occurs takes place *inside the oil film* and not on the surface between the film and the metal.

The quality of an oil that gives the comparative measure of the friction generated is the *viscosity*, and this may be defined as its resistance to flow. By oil manufacturers it is generally expressed numerically compared to that of water taken as unity; but as known by the consumer it is only expressed roughly as light, medium, heavy, etc., terms that are more generally understood. The higher the viscosity the less fluid the oil, and the greater the corresponding liquid friction. The viscosity of an oil decreases greatly with an increase of temperature, and at the working temperature in the cylinders even the heavy motor oils have their viscosities reduced to about that of a turbine oil at its working temperature.

Figure 1 will show this graphically. Oils A, B and C represent the heavy, medium and light grades of a well-known brand of Pennsylvania (paraffine base) oil. Oil D represents a heavy* oil of asphalt base. It will be noted that the falling off in viscosity with increased temperature is much greater in the case of the heavier grades. Also the viscosities of the Pennsylvania oils are maintained slightly better with increased temperatures.

* The viscosities of the light, medium and heavy grades vary with the different brands. Two "medium" oils, of different brands, for instance, may differ greatly in viscosity.

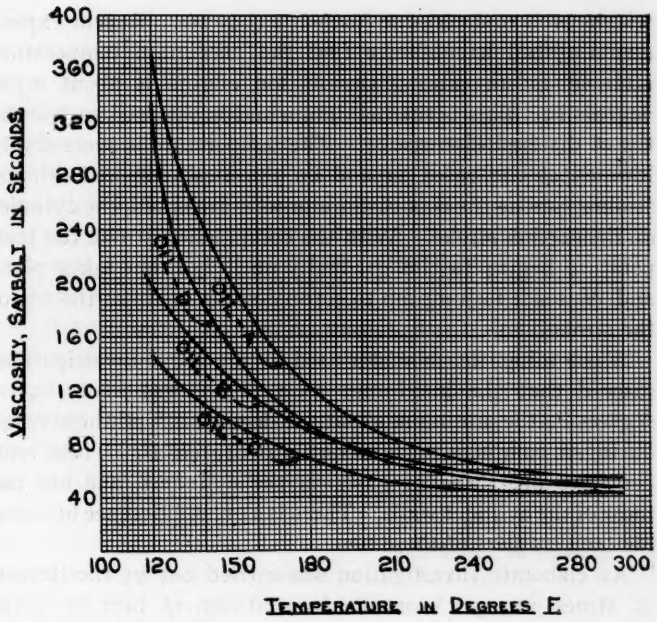


FIG. 1.

The deciding factor with regard to viscosity is the condition of the piston and rings. If these are tight, a light oil will give good results. If they are badly worn and loose, a heavy oil becomes necessary. If the oil is too light, too much of it will be drawn past the piston rings on the suction stroke. Likewise on the compression stroke some of the gaseous mixture from the carburetor will leak past the piston rings and condense in the crank case. As the gasoline which condenses in this way will tend to make the oil still lighter, this effect will be cumulative. Under the conditions of high rubbing speed and small piston-ring pressure that are generally found in motor cylinders, light oils, such as are used in turbines, would probably give the most efficient results if it were not for the high temperatures encountered in the cylinders.

Before discussing the effect of these high temperatures, it

will be well to determine just what they are. Recent experiments abroad have shown that the maximum temperature attained in an internal-combustion engine is about 2,700 degrees F. This is the maximum and is obtained only at the top of the explosion stroke. The temperature is successively lowered as the gases expand on the explosion and exhaust strokes, and as the cool carburetor mixture enters the cylinder on the suction stroke. With the compression stroke the temperature begins to rise gradually until ignition takes place and causes it to jump up to 2,700 degrees again at the top of the stroke.

A recording thermometer used in the above investigations showed that the maximum temperature was about 2,700 degrees F., the minimum about 250 degrees F., and the average during a complete cycle about 950 degrees F. These temperatures are those of gases in the cylinders, and are not those of the cylinder walls. There is a great difference between the temperatures of these two.

An elaborate investigation was carried out by the Bureau of Mines in 1912* on the transmission of heat in steam boilers, and the successive drops in temperature due to the different media were determined. With the hot moving gases in the boiler at an average temperature of 1,550 degrees F., and the maximum of 2,700 degrees F., and the water in the boiler at 350 degrees F., the following results were obtained:

	Temperature drop, in degrees F.	Percentage of total drop.
Drop in temperature between moving gases and dry surface	1,047	87.3
Drop due to layer of soot on tube	65	5.4
Drop due to thickness of metal	13	1.1
Drop due to layer of scale on water side of tube	65	5.4
Drop between scale and water	10	0.8
Total	1,200	100.0

*Bulletin No. 18, of the Bureau of Mines, 1912, "The Transmission of Heat into Steam Boilers."

In an internal-combustion-engine cylinder the conditions are almost identical except that the temperatures are lower, and there is very little scale on the water side of the cylinder. There is no layer of soot if the cylinder is in good condition, but there is a film of oil on the cylinder walls which would have about the same effect. The point which it is desired to emphasize is the great difference in temperature between the moving gases in the cylinder and the cylinder walls, since this has a very important bearing on the lubrication.

Let us assume that the cooling water in the jacket is at a high temperature—say 200 degrees F., just below the boiling point. Using the average temperature found for the moving gases in a complete cycle (950 degrees F.), this gives us a total difference in temperature between these gases and the cooling water of 750 degrees. If we apportion this drop in the same way as for a steam boiler we have:

	Percentage of total drop.	Temperature drop, in degrees F.
Between moving gases and dry surface.....	87.2	654
Drop due to film of oil, assuming it to be the same as for layer of soot.....	5.4	40
		694

which would give us the temperature of the inner surface of the cylinder walls as 950 — 694 = 256 degrees F.

Perhaps a more convenient way would be to figure this from the other end, that is, to determine the difference in temperature between the inner surface of the cylinder wall and the circulating water in the jacket. Under the same assumptions as above, this would be 7.4 per cent. of the total drop, which would give a difference of 56 degrees F. If we take the temperature of the circulating water as 150 degrees F., we get a difference of 58 degrees, so we can assume that the temperature of the cylinder walls is about 55 to 60 * degrees higher than that of the circulating water. As long as

* Since this was written some actual experiments conducted have given values of only 30 degrees. See "Steam as a By-product of Internal-combustion Engines," by J. B. Merriam, "Practical Engineer," November 15, 1914.

the water is not boiling we know that the temperature of the walls is little, if any, higher than 267 degrees F.

In air-cooled motors the temperature would be somewhat higher due to the less efficient method of cooling the cylinders. This does not mean that it would become too high, however, as it has been repeatedly demonstrated that properly designed air-cooled motors do not heat up excessively. The lubrication of this type of motors is more difficult at any rate.

With Diesel engines the *maximum* temperature is lower than in ordinary gasoline motors. Since ignition is by temperature of compression, the heating effect begins on the compression stroke; and since combustion is at constant pressure, the resulting *average* temperature in a cycle will be slightly higher. As long as these motors are water cooled, however, the temperature cannot exceed 267 degrees F. without the water boiling.

It was mentiond previously that there was a vast difference between the temperature of the hot gases and the cylinder walls. It naturally follows that the inner and outer surfaces of the oil film will be exposed to quite different conditions. The inner surface is exposed to the high temperature of combustion, and without doubt is very greatly damaged thereby. The outer surface is exposed only to the comparatively low temperature of the cylinder walls, and with a film of any appreciable thickness would be protected from the heat due to low conductivity of this film.

We can consider the film as consisting of two layers, the function of one of these being to furnish the lubrication, and of the other being to withstand the destructive action of heat and to protect this lubricating layer. It is well known that an exceedingly thin layer will furnish lubrication, and it is probable that the greater part of the thickness of the film is used up in giving the requisite protective action from the heat. At any rate, the part that we must look to for lubrication is that part having the lowest temperature, which is the very thin layer next to the cylinder walls.

The action of heat on oils is indicated by two properties,

the flash point and the fire point. The *flash point* of an oil is the temperature to which it must be heated in order that the vapors given off will give a slight explosion when a small flame is held immediately over the oil. The *fire point* is the temperature to which the oil must be heated in order that it will take fire and continue burning when a flame is applied. Roughly it is about fifty degrees higher than the flash point.

It is important that the flash point shall be higher than the temperature of the inner surface of the cylinder, otherwise the vapor given off by the oil will prevent it from adhering to the walls. We have seen that with the water boiling in the jackets the temperature of the inner surface of the cylinder walls will be about 267 degrees F. The temperature of the layer of oil that is in immediate contact with the cylinder walls, which is the part that regulates the friction, cannot be much higher than this. I do not know of any motor oils that have a flash point lower than 325 degrees F. If the temperature of the cylinder walls gets up to this temperature in a water-cooled motor there is something radically wrong, and the remedy is not to get another oil of higher flash point, but to locate the trouble and remove it.

It is an old theory that was never founded on solid facts that a high flash point is a necessity in a motor oil or the oil will burn up without giving any lubrication. The point was overlooked that, when we have a maximum temperature of the gases in the cylinder of 2,700 degrees F. and an average temperature of 950 degrees F., an oil with a flash point of 450 degrees F. will offer but little more resistance to burning than one would of 350 degrees F.

Either oil will burn if kept for any length of time in contact with the hot gas. Lubricating oil does not burn very easily or very fast, however, and the time given for it to burn in a motor cylinder is very short. A thin film of oil smeared on a hot (300 degrees) piece of iron or steel will burn for several seconds if ignited. Few motors ever run at less than 120 revolutions per minute, and at this rate the average point of lubricated surface on the cylinder wall would be exposed to

the action of the flame for only one quarter of a second. It is easily seen that there is no danger of all the oil film being burned in that short time, though there is no doubt that some of it is burned, whether the flash point is 300 F. or 500 degrees F. At high speeds the time allowed the oil to burn is so small a fraction of a second that we need not worry at all on this score. It would therefore appear that a flash point of 300 degrees F. would be sufficiently high for almost any water-cooled motor. Air-cooled motors might in some cases require a higher flash point, but 300 degrees F. should be sufficiently high for Diesel engines except in unusual cases.

The third requirement brings up the question of carbon in the cylinders. So much misinformation has been published on this subject that it will be well to look into the conditions resulting in its formation. In the first place, what is ordinarily known as carbon in the cylinders nearly always contains something else in greater or less quantity. Rust and small particles of iron are nearly always found. In automobile motors a large percentage of dust (silica) is generally present, and in marine motors and Diesel engines salt is a common constituent. In a case recently investigated at the Naval Engineering Experiment Station of an oil that was considered unsatisfactory on account of the large amount of carbon formed, a chemical analysis of the oil from the crank case that was supposedly full of carbon gave results about as follows:

	Per cent.
Free oil,	15
Water,	12
Rust,	11
Salt from sea water,	58
Decomposed oil,	2
Carbon,	1
Foreign matter,	1

Carbon may exist in a motor oil in two forms: First, as free carbon held in suspension, and, second, in combination with hydrogen forming the numerous hydrocarbon compounds

which go to make up the oil. The amount of free carbon in a well-refined oil is very small, and the objectionable carbon deposit is generally due to some other factor.

The conditions attained in the cylinders of internal-combustion engines that result in the formation of carbon are: First, high temperature, and, second, a limited supply of oxygen (air). References have been previously made in this article to the oil "burning." This term has been used rather loosely, as, strictly speaking, "burning" means the combining of the vapors from the oil with the oxygen of the air, and does not include simple vaporization of the oil. Unless air is present in excess of that required for the combustion of the gasoline or fuel oil, and usually it is not, the oil cannot really burn. Under the intense heat, however, the inner surface of the oil film will be vigorously affected, and, in the absence of the air necessary for burning, three things may happen:

Case 1. The compounds may volatilize without decomposition.

Case 2. The compounds may decompose with the formation of free carbon and hydrogen.

Case 3. The compounds may decompose with the formation of other hydrocarbon compounds of a different nature.

The products formed in case 1 give no trouble, as, being gaseous, they are carried out with the exhaust, whether burned or not. Of the products formed under case 2, the hydrogen would pass out of the exhaust, whether burned or not. The carbon may be blown out with the gases, or may remain in the cylinder. Whether or not it remained in the cylinder would depend greatly on the condition of the oil film on the cylinder walls. Some oils form a thick, viscous, gummy, asphalt-like deposit, which retains the carbon formed on its surface and prevents it from being blown out through the exhaust. This gummy deposit gradually gets thicker and harder, eventually forming the hard "carbon deposit" so well known in cylinders.

This gummy deposit is due to the action of the compounds mentioned in case 3. The free carbon liberated in case 2 is light and fluffy, and of itself would not form the hard deposit.

Where the compounds break up into new compounds, however, some of the new compounds are volatile, while others are heavier and more viscous than the original compound. Continued action of the kind mentioned in case 3 will therefore result in the gradual thickening of the film; and the retention and absorption by the film of the carbon that is liberated will increase this effect until, finally, a hard, brittle deposit results.

In the absence of any gummy deposit of this kind to cement the free carbon together, the latter will generally be blown out through the exhaust. The oil that will give the best results, then, is not necessarily the one that will *form* the least carbon, but the one that will *form the least carbon in the cylinders.*

Oils made from the Southern-asphalt-base crudes have shown themselves to be much better adapted to motor cylinders, as far as their carbon-forming proclivities are concerned, than are the paraffine-base Pennsylvania oils. The carbon formed from the latter is, as a rule, extremely hard and clings to the metal surfaces, while that from the former is soft and can easily be wiped off any surface that it is deposited on. This would be expected from a consideration of the nature of the hydrocarbons composing the oil, and it has also been demonstrated in practice.

The explanation lies in the fact that the paraffine-base oils are generally composed of the paraffine series of hydrocarbons, while the asphalt-base oils are composed mainly of the ethylene and napthene series. One of the characteristics of the latter two series as compared with the paraffine series is their tendency to distill without decomposition. Consequently no gum will be formed on the cylinder walls, and the carbon liberated will be mostly discharged with the exhaust gases.

In the light grades of motor oils there would probably be very little difference between the two varieties, but in order to get oils with a high viscosity in the paraffine brands it is necessary to compound the light oils with cylinder oil in different proportions. The presence of this cylinder oil is what is responsible for most of the gumming, and this explains

why the heavy oils give so much more carbon trouble than the light oils. Oils from an asphalt base can be made with viscosities sufficiently high to make it unnecessary to compound them with cylinder stock.

Some oil companies, in their advertising, lay great stress on the color and specific gravity of their oils. The color of an oil has no relation to its lubricating value. About the only information of any value that can be obtained from noting the color is whether or not it is a light oil compounded with a cylinder oil. If such is the case it shows the familiar greenish tinge of the cylinder oil.

The specific gravity is of no practical value to the consumer. The producer uses it to advantage in his refining. It might be used in conjunction with the flash point to determine what particular kind of crude a straight oil is made from, but it would take almost an expert to do this.

It will generally be found the best policy to use a lighter oil in winter than in the summer. There is generally very little difference in the working temperature of the cylinder walls in winter and summer, but the temperature of the crank case will show very great differences. If the oil is very viscous, due to low temperature, it will not splash very easily and too little oil will be supplied the cylinders. This will be particularly apparent when starting the engine. The *cold point*, which is the temperature at which the oil freezes, should be sufficiently low to insure that no difficulty will be encountered at the temperatures to which the crank case will be exposed. Otherwise it is of little value. The asphalt-base oils have a lower cold point than the paraffine oils. The heavy oils are usually the only ones that have cold points that are not sufficiently low.

The amount of oil necessary for the lubrication of motor cylinders depends on so many factors that no data can be given, and it will be necessary to solve the problem for each individual motor. The heavier the oil the less the amount that will be used ; also the tighter the piston and rings the less will be used. It is also well to remember that to use

more than is necessary for proper lubrication simply aids in the formation of carbon.

Two-cycle motors can be successfully lubricated by mixing the lubricating oil with the gasoline in the gasoline tank. The proportion generally used is about one pint of oil to five gallons of gasoline. In this method of lubrication the oil must vaporize in the carburetor and be carried with the gasoline vapor into the cylinder, where it will condense on the walls. In choosing an oil for this method of lubrication attention should therefore be paid to the characteristics governing its vaporization.

Gasoline, kerosene, lubricating oil and most all other products obtained from crude oil consist of a large number of different kinds of hydrocarbons, each of which has its own boiling point. When the oil is heated the lighter hydrocarbons will first vaporize, being followed by the others as their boiling point is reached.

If we take a mixture of gasoline and lubricating oil and heat it so as to cause it to vaporize, the gasoline will be driven off and the oil will remain, unless we select such conditions that the oil will also vaporize without leaving any residue. In the carburetor conditions are made very favorable for vaporization, but it will help appreciably if an oil is selected that has a low flash point and is easily vaporized. The writer has in mind a case that was brought to his attention a few days ago of a motor-boat engine that gave considerable difficulty owing to the oil congealing in the carburetor in cold weather.

The study and application of the foregoing principles to the selection of a motor oil for use in any particular engine should enable anyone to obtain an oil that is suited to that engine. It should also clear up some of the obscurity regarding the reasons why an oil will work well in some engines and will not in others. The writer believes that the formation of carbon in the cylinders of internal-combustion engines is an evil that can be prevented by a little study of its causes.

TESTS OF MATANUSKA COAL,
U. S. S. MARYLAND.

From Report of a Board consisting of Captain Philip Andrews, U. S. Navy; Lieutenant Milton S. Davis, U. S. Navy; Lieutenant H. E. Kays, U. S. Navy, and Ensign W. O. Henry, U. S. Navy.

ORDER OF TESTS.

(1) *Seven-day port test;* 4:00 A. M., November 7th, to 4:00 A. M., November 14th, 1914; test held at the Navy Yard, Puget Sound, Wash.

(2) *Four-hour full-power test;* 1:30 P. M. to 5:30 P. M., November 14th, 1914; test held in Puget Sound and Straits of Juan de Fuca.

(3) *Twenty-four-hour fifteen-knot test;* three-quarter boiler power; 10:45 A. M., November 15th, to 10:45 A. M., November 16th, 1914; test held in the Straits of Juan de Fuca and Pacific Ocean en route to Mare Island, California.

(4) *Forty-eight-hour ten-knot test;* 12 noon, November 16th, to 4:00 A. M., November 18th, 1914; test held in the Pacific Ocean making passage to Mare Island, California.

SEVEN-DAY PORT TEST.

Boiler No. 8 was used during the entire week. The usual auxiliaries were run; evaporators were used when necessary for filling the ship's tanks. The load on the ship was rather heavy; somewhat heavier than with that during the tests of Pocahontas or Bering River coals. It will be seen by attached data sheets that the load is proportionate to the total water evaporated. The water evaporated was measured as in previous tests.

The port auxiliary machinery and condenser were used. All steam drains were led into the port feed tank. Water was pumped across to the starboard feed tank, where it was measured before pumping into the boilers. All coal, ash and clinker were weighed; during day watches of two days the load was so excessive for one boiler that it became necessary to assist the draft by running the blowers. Run-of-mine coal was used for five days, slack for one day and lump coal for part of one day. There were no casualties. Data was very carefully collected by the assistant engineer officers, who stood a strict watch during the test. At the conclusion of each watch the assistant engineer officer submitted a report of data for his watch on forms which had been previously prepared. During this test the coal burned very freely. The firing was very good, the analyses of the flue gases giving rarely below 9 per cent. of CO_2. There was little clinker, but the ash was several per cent. higher than with the Pocahontas coal. The firing was carefully supervised, the officer on watch and chief water tender being present at all times. The draft was good and the coal burned with bright, yellowish flames. The coal coked very nicely; the coke was friable and very easily worked by the firemen. Fires six to eight inches thick were carried most of the time, though occasionally they were heavier. Two fires were cleaned each watch, although they might have been operated longer. The ash fused into clinker on the grate bars, generally about two inches thick, medium weight, porous, a little tough and hard while hot, but friable when cold. The clinker had a little ash mixed throughout the mass. It stuck a little to the bridge wall, but not seriously. The soot deposit was about 25 per cent. more than with Pocahontas coal. The soot was a little different from that of the Pocahontas, as the granules appeared as minute fused grains.

The work of firing this coal was easy for the firemen. Hoes were used for spreading the fires, which were kept level. The slice bar was used sparingly. The load of the ship was carried with ease except when coaling ship or cleaning up

after coaling, when there was a heavy drag on the boiler and the draft had to be assisted by the blowers. The load during this week of test would have ordinarily required two boilers burning Pocahontas coal.

FOUR-HOUR FULL-POWER TEST, FORCED DRAFT.

The *Maryland* stood by to get underway at 8:30 A. M. with all boilers, but, owing to the fog, she was unable to get underway until 11:19 A. M. The speed was gradually worked up to 120 turns about 1:30 P. M., when the test commenced. The fires had been worked and the ship made 108 turns under natural draft when the blowers were started and a draft of about one inch of air pressure in all firerooms obtained. The speed of 119 to 120 turns was very easily made. The fires were carried thin; blowers regulated to about 350 revolutions; dampers were partly shut. After all the fires were in good condition it was possible to regulate the steam pressure by operating the ash-pan doors. A very uniform steam pressure was carried, as will be seen in the attached data sheet of gage pressures. The fires burned brightly, the work of firing being very easy on account of the ease of breaking up the coke. The furnaces were one mass of yellowish flame. There was not an excessive amount of ash formed. The men, on being questioned, all said that it was the easiest twenty-knot run that they had ever made.

TWENTY-FOUR-HOUR FIFTEEN-KNOT TEST.

The *Maryland* anchored in Port Angeles after the four-hour forced-draft test. During the evening and following morning the usual cleaning work was done on all boilers; ash pans and furnaces were hauled and all ash and clinker separated and weighed. Tubes were blown with steam and all soot boxes hauled. The furnaces were primed with Matanuska coal. Boilers Nos. 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 were lighted up. At 10:00 A. M. the *Maryland* got underway and stood to sea, setting a course for San Francisco

Bay. By 10:45 A. M. the speed had reached 85 turns, which was the speed set to make 15 knots, and the test began. Data was collected as per sample forms. It soon became evident that the boiler power was much too great for the speed if the fires were to be properly worked in order to get the highest efficiency. Boilers No. 4, 6, 15 were first banked and then allowed to die out. No. 16 boiler was banked and the speed maintained with eight boilers. The firing was by signal, the intervals being about nine minutes. The same general remarks apply to the burning of the coal on this test. It burned with the greatest of ease, forming a very easily-worked coke, not an excessive amount of ash or clinker and, in general, appeared to be easier to handle than the Pocahontas coal. The CO_2 found in flue analyses was generally high, over 9 per cent. Fires, carried about six to eight inches thick, were always glowing, ash pans bright and the furnaces a mass of yellowish incandescent flame. The coal burned like pine knots. The amount of clinker was not excessive, was more or less easy to work and was very friable when cold. The fires were noticeably hot. The amount of soot made was a little higher than is generally made by good Pocahontas coal, about 10 per cent. more.

TEN-KNOT TEST.

This test was commenced at 12 noon, November 16th, the fifteen-knot test having been finished at 10:45. Ash pans and furnaces were hauled; tubes blown and soot boxes hauled; all fires were cleaned and were built up. Boilers Nos. 9, 10, 11, 12, 13, 14 were used, but, as in the fifteen-knot test, it was found that there were too many boilers for working fires properly. Two boilers were ultimately cut out and the test made with four boilers, which were more than ample, as, at times, there were four evaporators in use. The same remarks as to the fires on the fifteen-knot test apply to this test. Fires were very easily worked; the coke broke up easy; clinker was not very hard; bright, level fires from six to eight inches thick and sometimes thicker were carried, and the CO_2 was

generally high. After running forty hours it was found there were but three tons of Matanuska coal left, so the test was considered completed after forty hours.

GENERAL.

The Matanuska coal was delivered by the steamship company to the coaling plant at the Navy Yard, Puget Sound, where it was stowed under cover. At the time of the arrival of the *Maryland* it was still sacked. Some of the sacks had became rotten and a little coal had been spilled on the floor of the dock. The coal was inspected by the officers of the Board and the assistants in the engineering department. It was found to be very slack, as will be seen in the data sheet; also, it was very dry. There were very few lumps larger than a man's fist. A large working party under Ensign Bowden was sent to the coal sheds to load the coal on lighters. Every bag was weighed and spread out for inspection. All extraneous matter observed was picked out. There was very little slate, not over two hundred pounds being picked out of the whole lot of 586 tons. About forty tons was laid aside and screened into two sizes, that which would go through a quarter-inch mesh and that which would not. Of the former there was about twenty-five tons and of the latter about fifteen tons. This coal was burned on successive days, one day being devoted to the slack and a part of another day to the lump. The slack appeared to burn better than the lump, and the reason will be seen in the chemical-analyses sheet attached. When the lighters were filled they were towed alongside the ship and the coal was stowed in bunkers which had been previously swept clean. During the test there was no evidence of any gases being given off the coal. During the loading, in order to avoid dust, the coal was thoroughly wet down, but even with this precaution it was very dusty. The noticeable characteristic of this coal is its friability. Lumps pulverize very easily. This accounts for the chemical analysis, which shows the slack to contain less extraneous matter than the

lump. It will be seen that the coal, being friable, powders very easily, while the lump contains more or less shale and is hard. In this respect the coal shows a marked difference from the Bering River coal, where the lumps contained a small per cent. of extraneous matter while the slack contained about 30 per cent. Before loading the lighters samples at random were taken from the pile. These were sized into slack, buckwheat and lump, and were taken to the chemist for analysis as to ash. These samples contained from six to ten per cent. of ash and, on account of this showing it was decided that nothing further than hand cleaning would be necessary.

PHYSICAL AND CHEMICAL CHARACTERISTICS.

Moisture: There was apparently no free moisture on inspection before loading. This coal was stowed in a dry place and was extremely dry and dusty. Density 40.3 cubic feet per ton alongside and 39.8 cubic feet per ton at coal dock.

Sample: The laboratory was obtained by taking a shovelful out of every fifth bag as it came on board the lighter. This was bagged and stowed in a dry place. There were about fifty bags in this pile. On the day the laboratory samples were taken these bags were dumped out and the pile thoroughly mixed. As this pile was about five tons in weight, it was reduced and every fifth shovelful saved. It was again quartered and then quartered again. This gave a 325-pound sample, which was taken on board ship and then quartered and pulverized until there was a proper amount for chemical analyses and shipment to the Bureau of Steam Engineering and the Bureau of Mines.

General sample: Results of analysis are as follows:

Moisture, per cent	0.73
On dry basis:	
Volatile combustible matter, per cent	20.29
Fixed carbon, per cent	69.32
Ash, per cent	10.39
Sulphur, per cent	0.49

	Slack.	Buck-wheat.	Lump.
Moisture, per cent	0.75	0.65	0.63
On dry basis :			
Volatile combustible matter, per cent	20.96	20.22	19.47
Fixed carbon, per cent	70.85	70.50	65.19
Ash, per cent	8.19	9.28	15.34

Analyses by Mr. North, Yard Chemist, Navy Yard, Puget Sound.

A sizing sample of 785 pounds was obtained which gave the following:

Lump which would not go through a one-half-inch mesh screen, 17.7 per cent., 139 pounds.

Buckwheat which would not go through a one-quarter-inch mesh screen, 12.1 per cent., 196 pounds.

Slack which would go through a one-quarter-inch mesh screen, 70.2 per cent., 551 pounds.

Slate: There were no impurities in this coal of any consequence. Little or no slate could be found.

Calorific value: This could not be obtained.

Smoke: This coal makes some smoke, considerably more than Bering River, and about the same amount as Pocahontas.

Indicator cards were taken once an hour during the full-power test and once a watch during the other tests. The horsepower found agreed with the curves of the horsepower on board for the twenty-knot test, but the fifteen-knot test and ten-knot test appeared to be somewhat under that generally found for that of fifteen and ten knots. The indicators are old and the results obtained were irregular.

CONCLUSION OF TEST.

At the conclusion of each test an inspection of the boilers was made. No warping or overheating occurred during the four-hour full-power run. During the fifteen knot test the uptakes of No. 7 boiler were warped a little. In the uptake of No. 13 boiler there were ten rivets pulled out and the uptake door sprung a little. A few panel doors on the boilers show signs of some of the insulation being burnt out. From

the above it will be seen that this coal has no bad effects on the boilers or uptakes. There were no other casualties.

There were seven grate bars renewed during the port test.

The work of this test has been entered into by the officers and men concerned with the greatest enthusiasm. No effort has been spared to obtain the best results. All other ship work has been made secondary to the coal test. The machinery and boilers of the *Maryland* functioned perfectly during all these tests.

Mr. S. B. Flagg, Engineer of the Bureau of Mines, was present in the firerooms during these tests. He did much to assist the ship's force in working fires and instructing the firemen in the best methods of obtaining efficient combustion of this coal. The Board is also indebted to Mr. Flagg for advice and assistance in compiling the data of this report.

COAL ACCOUNT.

Receipts.

(*a*) By invoice, tons	586.0
(*b*) By weight, tons	585.7
(*c*) By tally, tons	583.0
(*d*) By bunker estimate, tons	574.0

Expenditures.

(*a*) Loss in handling (due to fineness), tons	12.000
(*b*) Priming and preparatory to port test, tons	4.000
(*c*) *Port test, tons	116.185
(*d*) Priming and preparatory to 4-hour test, tons	45.000
(*e*) *Four-hour test, tons	85.849
(*f*) Coming to anchor, tons	8.000
(*g*) Priming and preparatory to 15-knot test, tons	19.000
(*h*) *Fifteen-knot test, tons	161.112
(*i*) Preparatory and cleaning fires for 10-knot test, tons	8.000
(*j*) *Ten-knot test, tons	120.582
Total, tons	579.728
Difference, tons	6.272
On hand, about, tons	3.000

Bunker Estimate: Inspection of Bunkers.

Before tests, tons	574.000
After port test, tons	450.000
After four-hour test, tons	328.000
After 15-knot test, tons	120.000
After 10-knot test, tons	3.000

*These quantities by careful tally or actual weight. Other figures by estimates.

After investigating and reconciling all data the Board submits the following tables of comparisons with Pocahontas, Bering River and Matanuska coals.

Chemical comparison of coal.—Samples of which the analyses are given below were taken from Pocahontas and Bering River coals tested by U. S. S. *Maryland* in 1913.

Name.	Moisture.	Volatiles.	Fixed carbon.	Ash.	Sulphur.	B.t.u.
Pocahontas	2.5	19.2	74.6	6.2	.75	14,660
	2.4	19.0	74.6	6.4	.65	14,600
Bering River	1.6	17.7	61.9	20.4	.65	12,180
	1.7	16.7	59.9	23.4	.60	11,740
	3.5	16.3	58.8	24.9	.60	11,410
	1.0	17.5	69.9	12.6	.60	13,434
Matanuska	.73	20.29	69.32	10.39	.49	*

* No apparatus available for making this determination.

Analyses of Pocahontas and Bering River coals supplied by Bureau of Steam Engineering. Samples of Matanuska coal are taken as herein described. Analyses of Matanuska coal by Mr. North, Navy Yard Chemist, Puget Sound.

Densities.

Pocahontas, average, cubic feet per ton 42.16
Bering River, average, cubic feet per ton 39.83
Matanuska, average, cubic feet per ton 40.30

Comparison of Port Consumption.

PORT TEST OF SEVEN DAYS.

Coal.	Total tons.	Gals. water evaporated.	Gal. of water per pound of coal.	Ash, per cent.	Efficiency, per cent.
Pocahontas	94.291	248.610	1.177	11.04	100.
Bering River	136.391	247.783	.811	36.6	68.9
Matanuska	116.185	305.446	1.173	15.8	99.6

FOUR-HOUR FORCED-DRAFT, SPEED, TWENTY KNOTS.

Coal.	Total tons burned.	Percentage of ash.	Smoke by scale.	Knots per ton.	I.H.P.	Pounds per I.H.P.	Steaming radius.	Average efficiency.
Pocahontas...	79.1	8.8	2.4	1.02	20,820.3	2.09	2,367.8	100
Bering River*	127.3	38.8	1.5	.60	13,992.3	5.32	...	...
Matanuska....	85.848	18.67	2.8	.93	19,929.15	2.32	2,000.2	91

* During this test speed of 20 knots could not be obtained.

FIFTEEN-KNOT TEST, TWENTY-FOUR HOURS.

Coal.	Total tons burned.	Percentage of ash.	Smoke by scale.	Knots per ton.	I.H.P.	Pounds per I.H.P.	Steaming radius.	Average efficiency.
Pocahontas...	153.155	7.6	1.25	2.38	7,083.	†2.01	4,781.	100
Bering River..	160.3	35.0	.60	1.09	7,600.	4.98	2,372.	43
Matanuska....	*157.212	14.59	1.99	2.29	6,142.37	2.15	4,796.3	95

* Allowance of three tons of coal used on boilers banked or cut out.

† I.H.P. taken from curve of revolutions and I.H.P., as data obtained from indicator cards irregular.

TEN-KNOT TEST, FORTY-EIGHT HOURS.

Coal.	Total tons burned.	Percentage of ash.	Smoke by scale.	Knots per ton.	I.H.P.	Pounds per I.H.P.	Steaming radius.	Average efficiency.
Pocahontas...	137.325	10.5	1.18	3.515	2,134	†3.08	7,077	100
Matanuska ...	*118.582	15.67	1.86	3.37	2,686.527	3.09	7,160.6	98

* Allowance of two tons for coal used on boilers banked and cut out.

† I.H.P. taken from curve, as data obtained from indicator cards irregular.

Bering River coal expended before this test.

Matanuska coal expended after forty hours.

The Board finds that this sample of Matanuska coal tested is suitable in every respect for use in the naval service.

DESCRIPTION OF THE REPAIR PLANT OF THE U. S. S. *VESTAL*.

By Lieutenant Commander L. J. Connelly, U. S. Navy, Member.

The *Vestal* is a vessel with an overall length of 465 feet 10 inches, extreme breadth of 60 feet 2½ inches, and a normal displacement of 7,720 tons. (When in service as a collier, before conversion as a repair ship, her loaded displacement was 12,585 tons.) She has two triple-expansion, vertical, inverted, direct-acting, three-cylinder engines of 7,500 horsepower, driving two three-bladed propellers. Speed, fourteen knots per hour. Steam being furnished by six B. & W. boilers at 180 pounds working pressure.

The *Vestal's* conversion from a collier to a repair ship was authorized by an act of Congress making appropriations for the Naval Service for the fiscal year ending June 30th, 1913.

The conversion required the installation of decks and galleries in the former cargo holds; the relocation of two of the original four masts, the masts being now so placed as to permit the use of traveling cranes in the shops. The installation of additional electric and pneumatic power and distilling apparatus was necessary. A number of structural changes were made: fresh-water tanks were built in between frames forty-three and forty-seven in order to carry potable water for the larger crew; the superstructure was extended aft to provide for an optical workshop, a general office, and a drafting room; skylights, sixteen feet by fourteen feet, were built to cover the original cargo hatches; six cargo ports, three on each side, were cut so as to give light and ventilation to the work shops and to facilitate the handling of work delivered alongside in boats. A towing engine has been installed aft, so that the ship may take another vessel in tow in case of necessity.

The layout of shops is as follows: No. 1 hold, frames twenty-seven to forty-seven, is now the *General Storekeeper's Store* for repair materials. In this compartment two platform decks and the hold proper are given over entirely to repair stores; over nineteen hundred sheet-steel bins, one foot high, one foot wide and three feet long, have been installed. A thousand or more of the bins have been divided into smaller spaces by sheet-steel division plates. Racks for the stowage of bar metals, pipe, sheet metals, lumber, etc., have been provided, giving, in all, stowage space for about eight thousand items of repair material. A visitor on board remarked that "It is like a three-story hardware store, being three stories deep instead of three stories high." A power hack saw is installed near the bar-metal storage. A computing scale for weighing out quantities of small articles is installed near the bins containing fittings, bolts, etc. The general storekeeper's department is a very important part of the repair ship, it being necessary to carry a working stock to cover all ordinary expenditures while the ship is away from a supply base.

The *Machine Shop* is located between frames forty-seven and sixty-four. The shop has two galleries (one to starboard, one to port) and a lower deck. The heavier tools are located on the lower deck, the lighter tools, in the galleries. A three-ton electric crane travels fore and aft the shop. All the machine tools are driven by independent electric motors. The starboard machine-shop gallery contains the following machine tools:

Two 12-inch × 6-foot lathes, driven by 1½-H.P. variable-speed electric motors.

Two 14-inch × 8-foot lathes, driven by 3-H.P. variable-speed electric motors.

One 16-inch × 10-foot lathe, driven by a 5-H.P. variable-speed electric motor.

One 18-inch × 6-foot lathe, driven by a 7½-H.P. variable-speed electric motor.

The six lathes mentioned above are of the "Prentice" high-

speed, geared-head type, and driven with silent-chain belts by Reliance motors of the 120-volt, semi-enclosed, variable-speed, direct-current type. The motors are placed at the lowest part of the head stock column.

The other tools on this gallery are:

One 2½-inch × 26-inch Acme flat turret lathe, driven by a 3-H.P. Reliance motor.

One Pratt and Whitney ⅝-inch × 4½-inch turret lathe.

One Hendey 4-inch centering machine, driven by a ½-H.P. constant-speed Reliance motor.

One 14-inch × 6-foot American Tool Company's geared-head lathe, driven by a 2-H.P. v. s. Westinghouse motor.

One 30-inch Mueller plain radial drill, driven by a 3-H.P. c. s. Reliance motor.

One 12-inch Willey electric-driven sensitive drill.

One Willey electric wet-tool emery grinder, the motor being contained in the pedestal.

The port machine shop gallery contains the tool cage, in which is kept for issue on check portable pneumatic and electric tools, hand tools, reamers, etcetera, also a Wilmarth and Morman combined cutter, reamer and twist-drill grinder, driven by a 1-H.P. General Electric motor; a Prentice 12-inch × 6-foot toolmakers' lathe, driven by a 1½-H.P. v. s. Reliance motor; and a Gorton engraving machine, driven by a ½-H.P. Reliance motor.

Outside of the tool cage, on the gallery proper, the following machine tools are installed:

One 12-inch × 6-foot Prentice toolmakers' geared-head lathe, driven by a 1½-H.P. variable-speed Reliance motor.

One No. 2-B, heavy, Brown and Sharpe, plain milling machine, with a 7½-H.P. c. s. Reliance motor.

One No. 3-B, Brown and Sharpe, Universal milling machine, with a 7½-H.P. c. s. Reliance motor.

One No. 4-S Cincinnati plain milling machine, with 10-H.P. c. s. Reliance motor.

One 16-inch Willey sensitive drill, electrically driven.

One Riehle 100,000-pound testing machine, driven by a 5-H.P. Crocker-Wheeler motor.

One Cincinnati electric-driven two-wheel bench grinder.

The lower deck of the machine shop contains the following tools:

One 18-inch × 8-foot Prentice geared-head lathe, driven by a 7½-H.P. v. s. Reliance motor.

One 18-inch × 10-foot Prentice geared-head lathe, driven by a 7½-H.P. v. s. Reliance motor.

One 32-inch × 14-foot Prentice geared-head lathe, driven by a 15-H.P. c. s. Reliance motor.

One 25-inch—39-inch × 6-foot—10-foot Harrington extension-bed gap lathe, driven by a 7½-H.P. c. s. Westinghouse motor.

One 48-inch—72-inch × 8-foot—15-foot Harrington extension-bed gap lathe, driven by a 7½-H.P. v. s. Reliance motor.

One 10-inch New Haven Manufacturing Company's slotter, with 3-H.P. c. s. Reliance motor.

One 18-inch × 30-inch × 96-inch Norton plain-cylinder gap grinder, driven by a 15-H.P. c. s. Reliance motor.

One 72-inch Franklin boring, drilling and milling machine, driven by a 10-H.P. c. s. Reliance motor.

One 72-inch J. M. Poole vertical boring mill, with a 10-H.P. v. s. Reliance motor.

Two 25-inch Snyder heavy-duty upright drills, with 2-H.P. v. s. Reliance motors.

One 36-inch × 8-foot Detrick and Harvey open-side planer, with 10-H.P. c. s. Reliance motor drive.

One 30-inch × 30-inch × 72-inch Woodward medium metal planer, driven by a 5-H.P. c. s. Reliance motor.

One 16-inch Flather heavy-duty crank shaper, driven by a 5-H.P. Reliance motor.

One 15-inch Potter & Johnston shaper, driven by a 1-H.P. c. s. General Electric motor.

One 24-inch Flather heavy-duty crank shaper, driven by a 7½-H.P. Reliance motor.

One Willey electric-driven wet-tool emery grinder.
One Willey electric-driven two-wheel emery grinder.
One Royal No. 8 power hack saw, ½-H.P. motor.
One 4-foot Drese's full universal radial drill, driven by a 5-H.P. v. s. Reliance motor.
One buffing lathe, with motor incorporated in the stand.
One 24-inch Bullard vertical turret lathe, driven by a 5-H.P. c. s. Reliance motor.
One Lovekin 7-inch pipe expanding and flanging machine, driven by a 25-H.P. Westinghouse motor.

A gage-testing outfit, vice benches, arbor presses, floor stand with chuck, portable Franklin cranes, portable boring bars for cylinders, and main-engine bearings, shaft-straightening press, and miscellaneous equipment have been provided.

The *Electric Shop* is located underneath the lower deck of the machine shop. It is fitted up with a work bench, armature horses, a Hendey lathe, and a small electric-plating motor generator for nickel plating.

Number three hold contains a coppersmith shop on the starboard gallery, a pattern-making shop on the port gallery, and the lower deck is a combination of blacksmith, shipfitter, and boiler shop.

The *Coppersmith Shop* outfit consists of:
One horizontal hydraulic pipe-bending machine, power being supplied by an electric-driven Gould's triplex power pump.
One 3-inch Stoever pipe machine, driven by a 3-H.P. c. s. Reliance motor.
One Watson-Stillman hand-power, hydraulic, stanchion pipe bender.
One hand-power sheet-metal folder.
One 22-inch upright drill, driven by a 1¾-H.P. c. s. Westinghouse motor.

Bench machines, hand tools, forges, compressed-air fuel-oil torches, and a lead-lining equipment, has been provided.

The *Patternmaking Shop* is located in the port gallery of this compartment and has the following machine-tool equipment:

One electric-driven band-saw filing machine.

One 36-inch × 60-inch × 14-foot Fay and Scott extension-gap patternmakers' lathe, with 4-H.P. Reliance motor.

One 12-inch Oliver motor-head patternmakers' speed lathe, with ½-H.P. Oliver v. s. motor.

One Crescent universal woodworker, driven by a 7½-H.P. c. s. Reliance motor. (This machine has a band saw, circular saw, shaper, jointer, morticer, borer and sand disc.)

One No. 2 Oliver universal wood trimmer.

One Crescent universal double-arbor saw bench, driven by a 5-H.P. c. s. Reliance motor.

Two No. 5 Fox bench wood trimmers.

One Crescent motor-driven hand planer and jointer, with 5-H.P. c. s. Reliance motor.

One 24-inch Wood's motor-driven surfacer, 7-H.P. motor.

One electric-driven oilstone grinder, equipped with the following wheels: one fine and one coarse oilstone wheel, one emery cone, one leather stropping wheel, and one emery wheel. Manufactured by Mummert Dixon Co.

One electric-driven jig saw, 6-inch stroke; motor, 1½-H.P.

One electric-driven friezing and shaping machine; manufactured by J. A. Fay & Co.; driven by a 3½-H.P. Westinghouse motor.

One electric-driven morticing machine manufactured by H. B. Smith Machine Co., with 3-H.P. General Electric motor.

One electric-driven 16-inch × 6-foot patternmakers' lathe.

Bench, tools, electrically-heated aluminum glue pots, saw-brazing equipment, etcetera, have been provided. A number of standard patterns (about 300) are on hand as part of the equipment.

The lower deck of this compartment is a combination of the smithy, ship-fitter, and boiler shops. Four forges, one tempering furnace, bending slabs, the oxy-acetylene cutting and welding apparatus, with usual anvils, work benches, a three-ton traveling crane, and miscellaneous tools, and the following power-driven machines, comprise the equipment:

One 150-lb. steam hammer, driven by compressed air.

One 150-ton high-speed hydraulic forging press. This is one of the Marine type, made by the United Engineering and Foundry Company of Pittsburgh.

One 30-inch Mueller plain radial drill, with 3-H.P. c. s. Reliance motor.

One 28-inch Newton cold-metal sawing machine.

One motor-driven hack saw.

One Wicke's Bros. double-end punch and shears. Punches and shears up to 1 inch, driven by a 7½-H.P. c. s. Reliance motor.

One Cleveland 6-foot geared motor-driven plate-bending roll, 10-H.P. Reliance motor.

One power shears for metal up to ½ inch, with 30-inch throat.

One 30-inch power rotary shears.

One electrically-driven wet-tool grinder.

The forges use low-pressure oil burners, the blast being furnished by a Connersville positive-pressure blower, driven by a 7-H.P. electric motor.

An electrically-heated oil-tempering bath (manufactured by the General Electric Co.), with necessary switchboard control, also a pyroscope and a sclerescope for testing hardness of temper, are provided. A Lincoln arc-welding (motor generator) outfit is installed in the starboard forward corner of this shop.

Number four hold contains the *Foundry*, on the lower deck; the *Coremaking Department*, on the starboard gallery; and the *Carpenter Shop*, on the port gallery.

The *Foundry* has one 1 to 2-ton cupola; one 2½ to 3½-ton cupola; the blast being furnished by a B. F. Sturtevant pressure blower driven by a 17½-H.P. electric motor.

There are four Rockwell tilting-crucible brass furnaces, two with working capacity of 200 pounds, and two with working capacity of 375 pounds, fuel-oil fired; their blast being furnished by a General Electric centrifugal compressor driven by a 10-H.P. General Electric motor.

A six-crucible steel furnace will shortly be installed, using oil and natural draft.

In one corner of the foundry is a small sand-blast room, also a metal-cutting band saw, electrically driven, for cutting off gates and sprues; and a two-wheel electric emery grinder for snagging castings.

A three-ton electric traveling crane is installed for handling the ladles, flasks and castings. The iron storage is underneath the foundry. A large sand pit is provided in the center of the compartment. A thermit welding outfit is carried in the foundry equipment. A sherardizing outfit has also been provided.

The *Optical Shop,* located in the starboard after corner of the superstructure, has the following equipment:

One Brown and Sharpe, No. 1½-A, universal milling machine, driven by a 3-H.P. Reliance motor.

One Pratt and Whitney 10-inch × 5-foot toolmakers' lathe, driven by a ¾-H.P. v. s. Reliance motor.

One Hendey 12-inch geared-head toolmakers' lathe, driven by a 2-H.P. Reliance motor.

One Rivett 8-foot × 22-inch precision lathe, driven by a ¾-H.P. v. s. Reliance motor.

One electric-driven bench-tool grinder.

One electric motor-driven bench buffing lathe.

One Hisey-Wolf electric motor-driven sensitive bench drill.

A small *Drafting Room* has been provided.

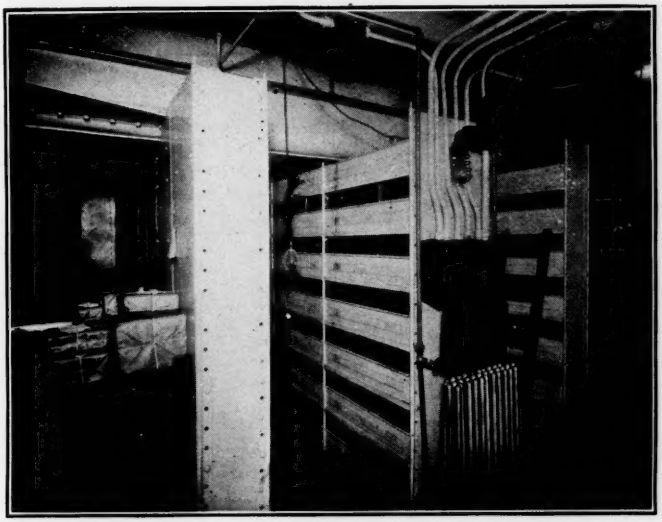
The electric-generating and air-compressing plant to furnish the ship with light and power consists of:

Two 85-kw. Turbo-generators, Curtis turbine and Diehl generators.

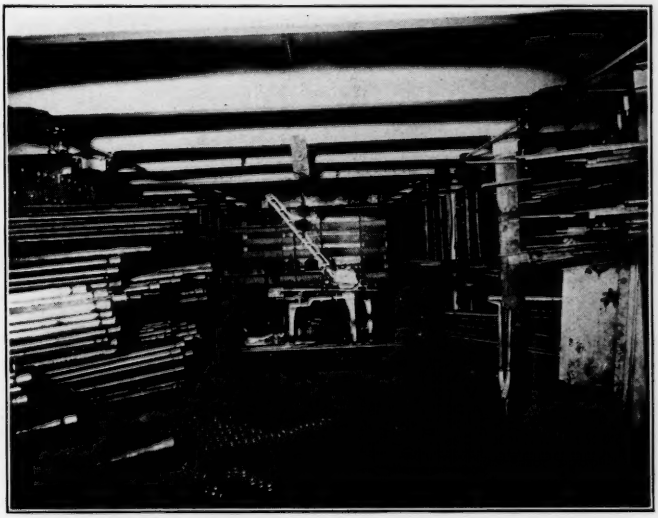
Two 32-kw. General Electric dynamos, driven by piston engines.

One Chicago pneumatic two-stage, compound, steam air compressor, delivering air at 100 pounds pressure throughout the ship. Capacity, 446 cubic feet of free air per minute.

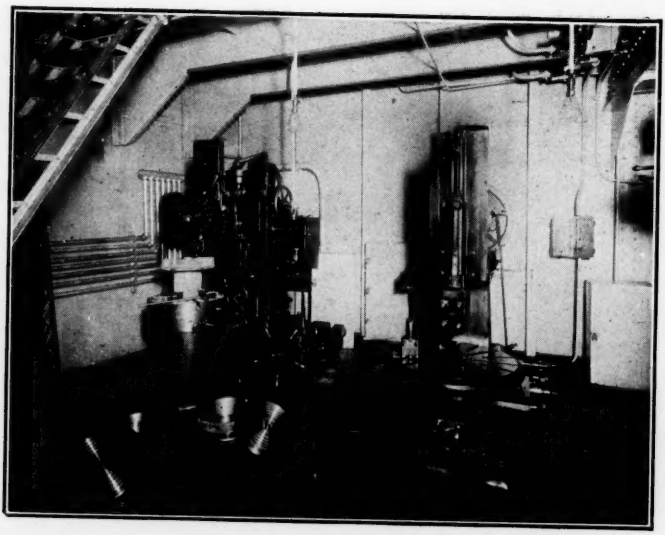
One Norwalk Iron Works steam-driven air compressor for



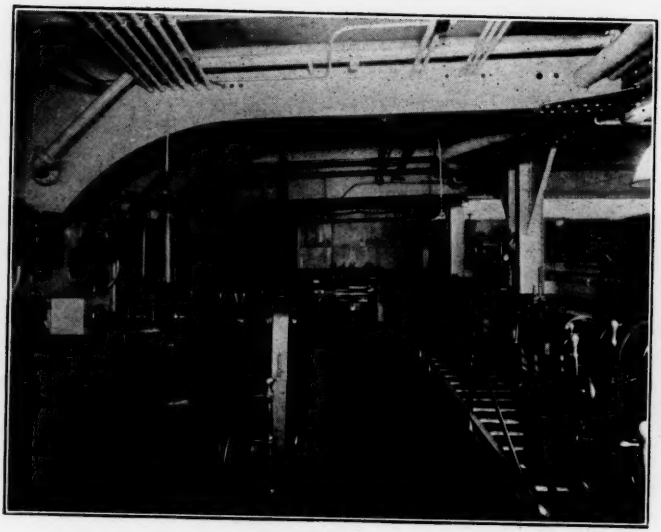
A Corner of the Upper Platform Deck in the General Storekeeper's Department.



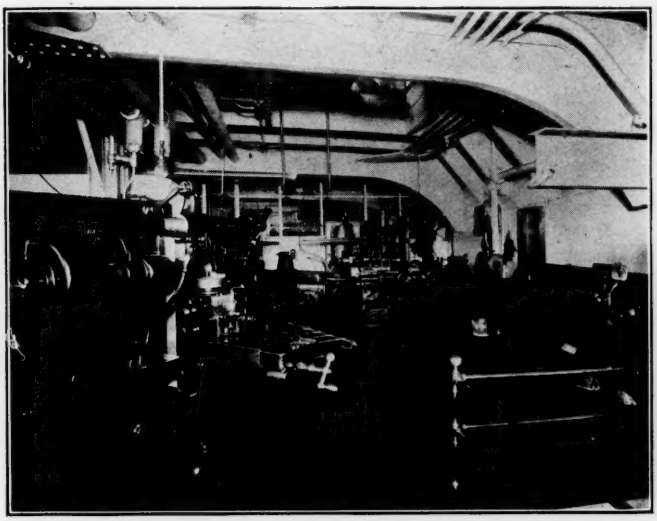
Part of Bar Metal and Pipe Stores.



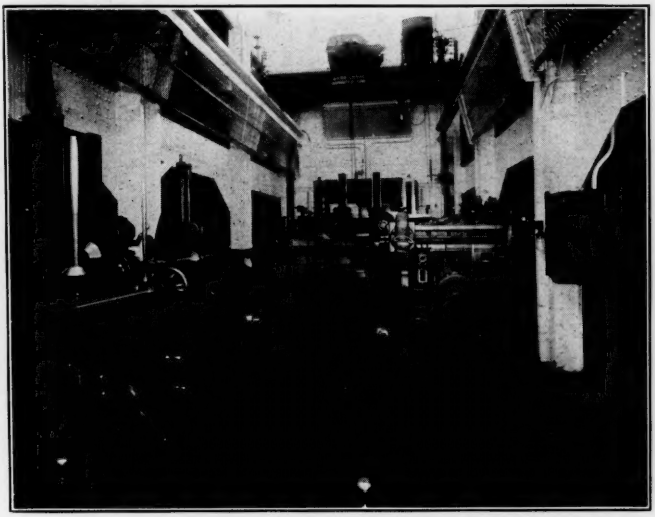
A Corner of the Machine Shop.



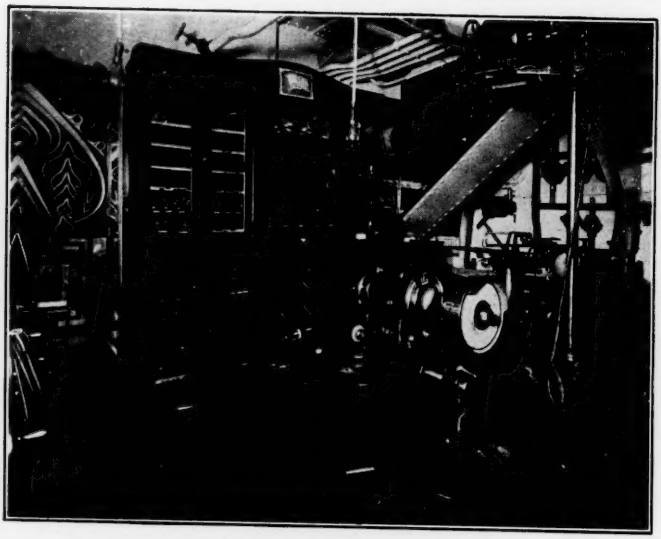
Part of the Starboard Gallery of the Machine Shop.



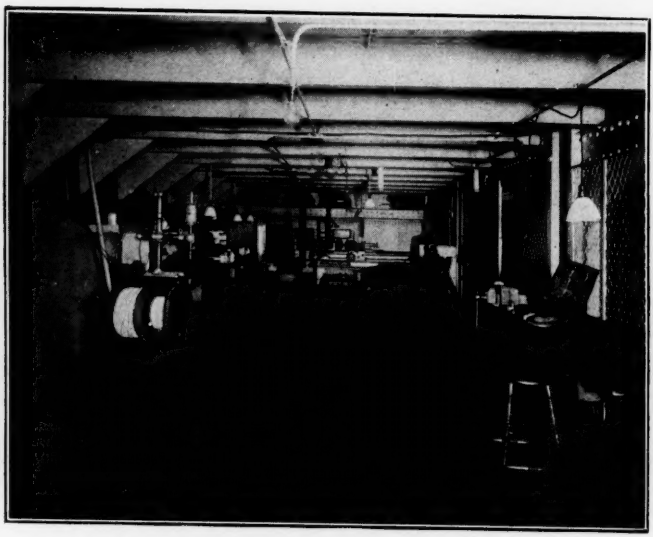
A Part of the Port Gallery of the Machine Shop.



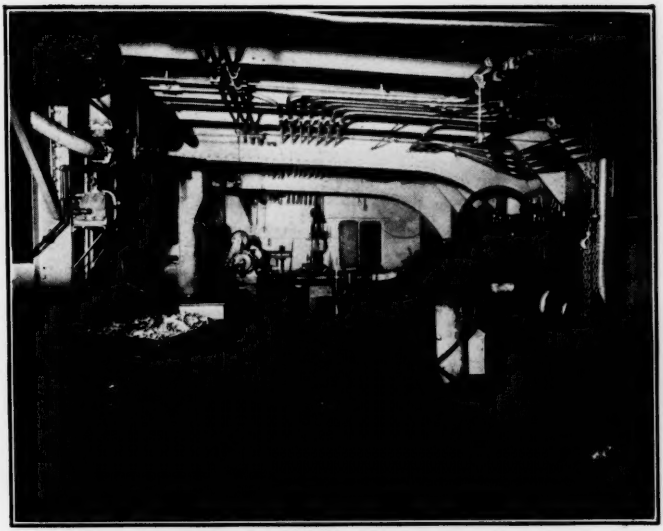
A View of the Center Part of the Lower Deck of the Machine Shop.



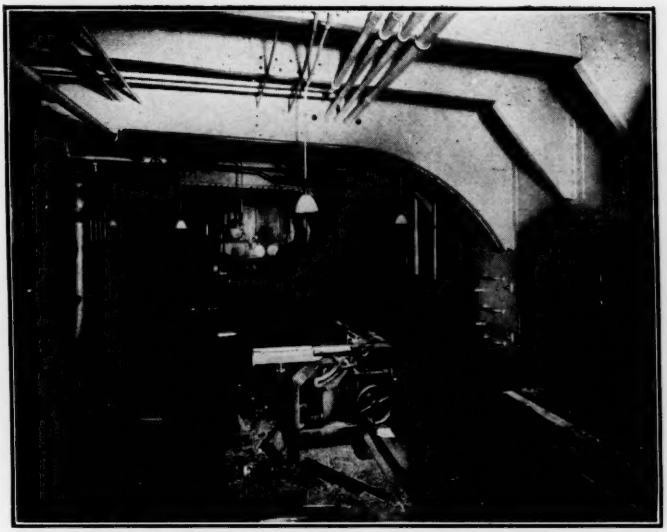
A View in the Tool Cage.



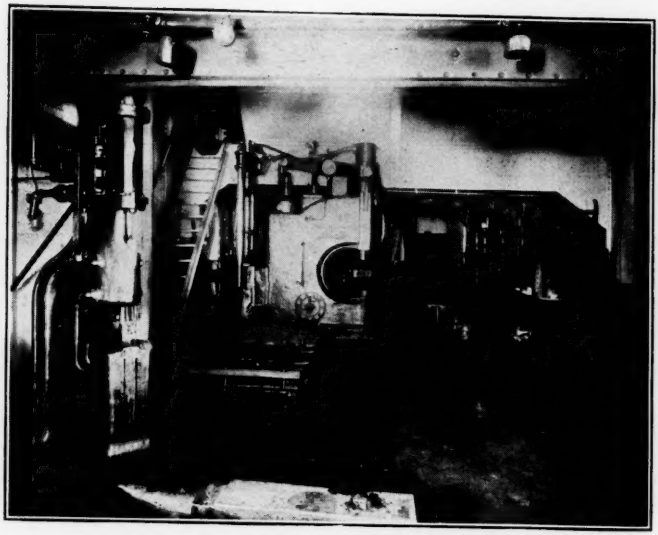
After End of Electric Shop.



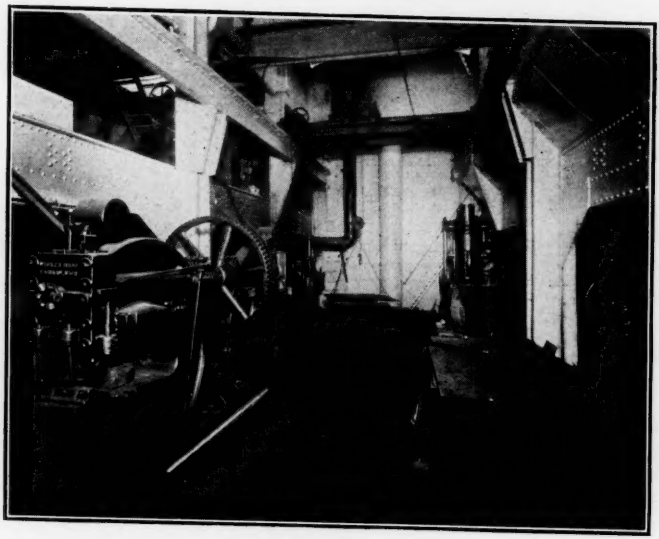
Coppersmith and Plumbers' Shop.



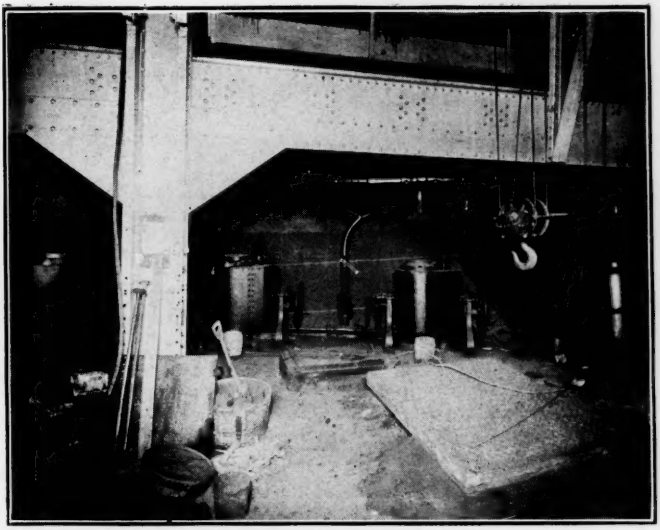
A View in the Forward Pattern Shop.



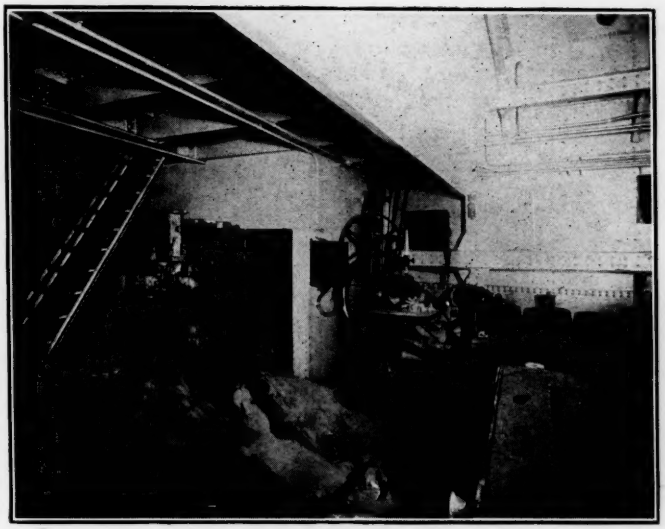
A View in the Smithy.



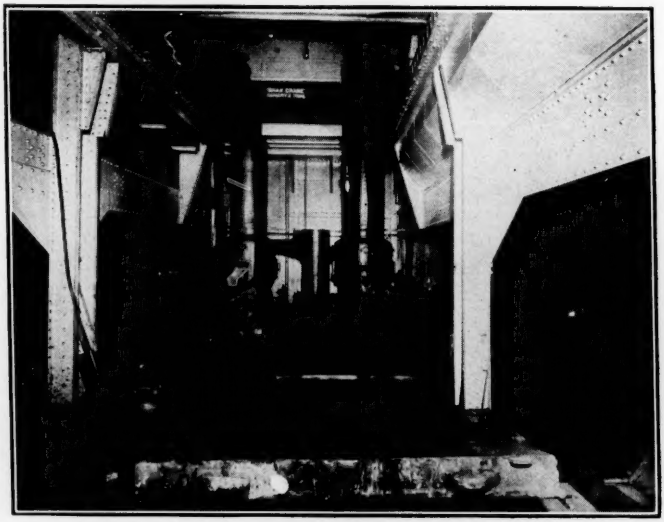
A View in the Smithy.



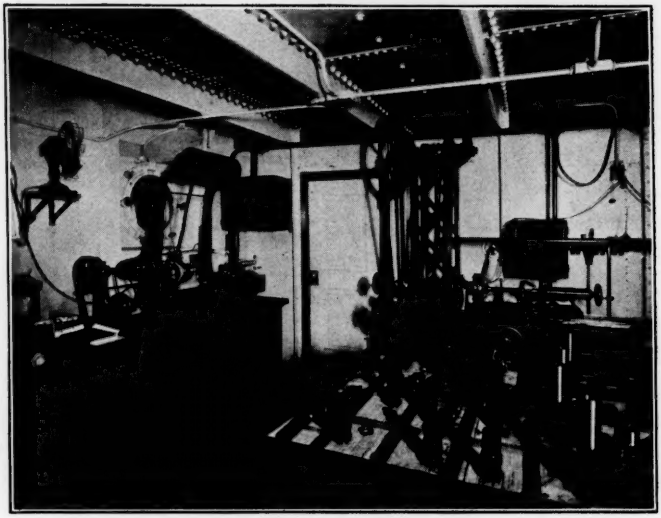
A Foundry View.



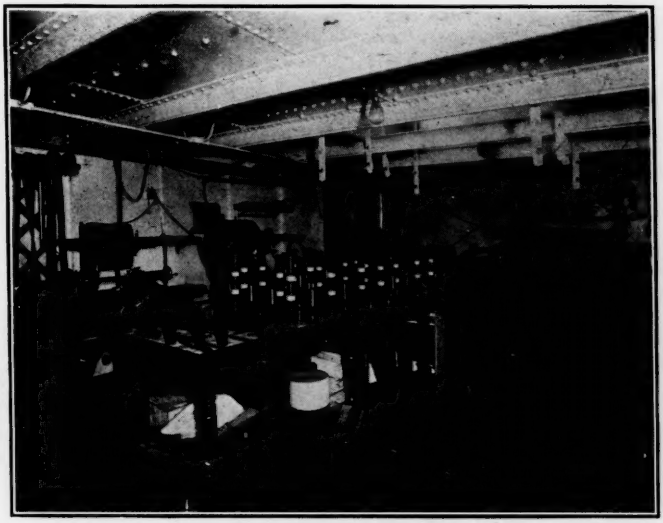
A Foundry View.



A Foundry View.



Optical Shop.



A View in the Optical Repair Shop.

torpedo charging, at 2,500 pounds air pressure, is provided for testing torpedo repairs. Capacity, 20 cubic feet per minute.

The *Vestal* is intended to give prompt repairs to vessels away from the repair yards, the repair ship anchoring wherever the Fleet is temporarily based. Articles to be repaired are usually brought alongside in the ships' boats; when necessary, the vessels themselves coming alongside the *Vestal*. During the five months' stay recently in Vera Cruz, Mexico, eight vessels were taken alongside for more or less extensive repair work.

The repair complement at the present time consists of:

24 Machinists' mates; this includes the optical repair men and the draftsman. The draftsman is also the Progress man.
3 Blacksmiths; this includes the oxy-acetylene operator.
3 Boilermakers; this includes the electric-welding operator.
1 Shipfitter.
4 Moulders.
2 Patternmakers.
1 Carpenter's mate.
6 Electricians.
4 Coppersmiths.
1 Yeoman (clerk).
1 Cook.
20 Helpers.
Total, 70 men.

This force has been found inadequate when with more than a dozen ships. The smaller ships frequently require more repairs than the larger ships, as the equipment of the smaller ships for repair work is usually very limited, and their opportunities for visiting the navy yards are less frequent than the large ships, which have regular overhaul and docking periods.

During seven and one-half months with the Fleet the following principal jobs have been completed:

In the *Optical Shop:*

269 Telescopic gun-sights.
18 Telescopic bore-sights.
25 Spotting glasses and periscopes.
44 Range finders.
78 Telescopes for O.O.D. and Quartermasters' use.
76 Binoculars for Ordnance and Navigation use.
32 Five-inch gun-dotter mirrors resilvered.
81 Stop watches, Ordnance.
41 Clocks, range-keeping and ordinary.
15 Stadimeters, Ordnance and Navigation.
4 Sextants.
4 Azimuth circles.
10 Typewriters.

Small parts for torpedoes, field-gun gear, battery commanders' scales and numerous incidental jobs.

The *Pattern Shop:* Manufactured 229 patterns with necessary core boxes. Much carpenter work being done for the ship, also the sawing and dressing of lumber for various ships of the Fleet. During the ship's stay of five months in Vera Cruz harbor, twelve carpenters' mates and patternmakers were busily employed in the pattern shop, and it was found necessary to extend this shop into the port gallery of the foundry.

The *Foundry:* Made 1,093 iron castings, 1,599 brass and composition castings, 25 monel-metal castings, and 9 aluminum castings. The largest iron castings made weighed about one ton. A six-crucible steel-melting furnace is about to be installed by the foundry force, the necessary drawings, castings, etc., having been made. To date the foundry force has been kept too busy to permit the installation. Two thermit welds on broken iron castings were made. One heat on the sherardizing apparatus was run to demonstrate the possibilities of this system.

The *Copper Shop:* Completed 170 jobs; this included the renewing of the inner shells of three 60-gallon steam-heated galley coppers, the manufacture of the exterior parts (sheet

steel) of sixteen field-artillery ammunition boxes, and about thirty-six ammunition saddle packs for the expeditionary forces in Vera Cruz. About six pairs of main-engine brasses and numerous auxiliary engine brasses were rebabbitted. The largest piece of copper pipe made was a 17-inch bend, the usual jobs being on a 1½ to 10-inch piping. In all cases where the pipes under repairs warranted a renewal, new pipe was made; in other cases, patches were brazed. The copper shop handles all classes of pipe and light sheet-metal jobs received aboard. During the ship's stay in Vera Cruz much overtime work was necessary in this shop, as the majority of the pipe jobs meant that some part of a ship's piping was out of commission until the pipe was returned.

The *Smithy:* This shop, being a combination of blacksmith, shipfitters' and boilermaker shop, handled a total of 534 jobs in the time mentioned; the principal forging jobs being the manufacture of heavy strongbacks, etc., for feed-water heaters, the forging of cargo-boom fittings, pistons for auxiliary engines, the making and repairing of firing tools, etc.

The principal boilermaker jobs were the building of a feed and filter tank for the *Patuxent;* the manufacture of two fresh-water tanks for the *Georgia,* and the renewal of the upper sheets of four of the steam drums of the *Nashville's* main boilers. One hundred and fifty-one oxy-acetylene jobs, and thirty-nine electric welds, were made by this shop. Several of these consisted of repairing ash-ejector piping where the cast-iron pipe was worn through at the bends by the scouring action of the ashes. In these cases a patch of steel plate was cut and bent to conform to the shape of the worn pipe, then the oxy-acetylene operator welded the patch in place. Some B. & W. boiler headers that were found to have developed open seams or pitted hand-hole seats were welded or built up. The jobs of this nature, being always urgent, were rushed through; on one occasion an ash-ejector pipe being patched and returned within one hour of its receipt. The battleship required this prompt action, as she was about to fill her bunkers, the ash ejector pipe passing through a bunker. On an-

other occasion a ship having only one refrigerating engine broke a cross-head. This was gas-welded, and the ship's supply of meats saved.

The *Electric Shop:* Rewound 29 armatures; of these, two 85-kw. and one 200-kw. armatures were the largest ones handled. A number of signaling lights were made; several field coils were rewound. The French cruiser *Des Cartes* availed herself of the *Vestal's* facilities to rewind the field coils of a dynamo. A small electro-plating generator has been provided.

The *Machine Shop:* Carried to completion 624 jobs. Some of these jobs required many machine operations on each article. On one job in mind 40 articles were made, each article requiring 30 machine operations. The variety of work in the machine shop ranged from repairs to artillery-horse collars and motor trucks for the expeditionary forces in Mexico, to work on the torpedoes and main engines of a battleship. The greater part of all jobs handled in any other shop, at some stage of their completion being worked on, in part, by the machine shop.

This being the first year of the ship's commission, a great deal of work has been necessary in making shop equipment. During the five months in Vera Cruz the *Vestal* operated the floating dry dock at that port, docking several of our smaller vessels, renewing bottom zincs, straightening propellers, and giving these ships in general an "overhaul period." In the case of the tug *Patuxent* (755 tons), she was docked, propellers straightened, H.P. cylinders of main engines rebored, new rings fitted, new main air-pump plungers were made to fit rebored cylinders, pumps overhauled, boiler furnace doors made, and so forth. The result was that her speed was increased two knots over what she was capable of making before overhaul. A number of small vessels, British and Mexican, were docked as a matter of courtesy and convenience to the vessels' owners.

A very simple system of job orders is used, giving the routing of the work, appropriation chargeable for material used,

MFB
No.348-14.

U. S. S. GEORGIA,
Vera Cruz, Mexico,
June 19th, 1914.

From: Captain.
To : Commanding Officer, U. S. S. VESTAL.

SUBJECT: Request repairs by Repair Ship.

REFERENCE: (a) Article 246, Fleet Regulations, 1913.

ENCLOSURES: (a) Blueprint, Georgia's No. 0416.

1. The following work under cognizance of the Bureau of Steam Engineering is requested. This work is beyond the capacity of the ship's force with the regular plant at hand. It is requested that it be completed as soon as practicable.

SPECIFICATIONS.

1. Cast and machine new expander crosshead for 3-ton Ice Machine, as per accompanying blueprint.

Signed. R. E. Coontz.

Original and 1st copy to VESTAL.

1st endorsement. U. S. S. VESTAL, Vera Cruz, Mexico.,
June 23, 1914.

To: Commanding Officer, U.S.S. GEORGIA.

1. Copy of job order No.617 is herewith enclosed.

Signed R. L. BEACH.

Exhibit A.

U. S. S. VESTAL FILE No. 617

JOB ORDER 617

FOR S.E. Dep't. U.S.S. GEORGIA.

CORRESPONDENCE C.O.Let. MRP #348-14. June 19, 1914.

JOB ORDER ISSUED June 23, 1914.

AUTHORITY /s/ E.L. Beach.
Commander, U.S.Navy?
Commanding.

SPECIFICATIONS

Manufacture 1 expander cross head for 5 ton ice machine.

PLAN OF WORK

Shop P. Make pattern from blue print.

Shop F. Cast from composition.
Shop M. Machine as per blue print.

Copies to:
C.O. GEORGIA.
C.G.K.
File.

Briefs to:
Shop P.

Shop F.
Shop M.

Exhibit B

U.S.S. VESTAL, June 3, 1914.

AUX.# brief.on J.O.# 617

For S.E. U.S.S. GEORGIA.

SPECIFICATIONS.

Manufacture 1 expander cross head for 3 ton ice machine.

Plan.

Shop P. Make pattern from blue print.
Shop F. Cast from compo.
Shop M. Machine as per blueprint.

Exhibit "C"

Estimated date comp'n.
Shop
"
"

Date Com'c'd. 6-26-14.
Date Comp'd. 7-3-14.

Material used in shop P has been charged against this job.

/s/ E.P.Schilling, U.S.N.
Officer in charge.

NOTES.

NAME	RATE	TOTAL HRS.
Bacon	CCM	22

40 ft. 4" white pine pattern lumber.
8 ft. 2" white pine pattern lumber.

Exhibit "C 2".

Estimated date comp'n.
Shop
"
"

Date Com'c'd. 7-14-14.
Date Comp'd. 7-23-14.

Material used in shop M has been charged against this job.

/s/ J.J.Cotter U.S.N.

Officer in charge.

NOTES.

NAME	RATE	TOTAL HOURS.
Luenzer	MM1c	60

Exhibit "C3".

U. S. S. GEORGIA

DATE 7/24/14

JOB ORDER No. 617

RECEIVED THE FOLLOWING ARTICLES:-

Cross head for 3 ton ice machine.

/s/ B. Anderson,
C.M.M., U. S. NAVY.

Exhibit "D"

Vestal Form No. 2

U. S. S. VESTAL — **N. S. A. TITLE "X" STORES**

Issued 6/26/ , 1914 To — Allotment, Vest — Qr.

or to — shop for J. O. No. 617 — U. S. S. GEORGIA

STOCK NO. ENTERED BY STOREMAN	UNIT	NO.	ARTICLES (One item only on each line. Please give full description)	UNIT PRICE
		40	Ft. B.M. 4" pine.	
		8	Ft. B.M. 2" pine.	
			For 1 expander cross /s/ E.P. Schilling.	
			Exhibit "E"	

Storeman's Initials — Received — Initials of person receiving stores — Head of Department

Vestal Form No. 2

U. S. S. VESTAL — **N. S. A. TITLE "X" STORES**

Issued 6/26/ , 1914 To — Allotment, Vest — Qr.

or to — shop for J. O. No. 617 — U. S. S. GEORGIA.

STOCK NO. ENTERED BY STOREMAN	UNIT	NO.	ARTICLES (One item only on each line. Please give full description)	UNIT PRICE
	Lb	110	Compo. G.	
			For 1 expander cross	
			/s/ E.P.Schilling.	
			Exhibit "E"	

Storeman's Initials — Received — Initials of person receiving stores — Head of Department

Vestal Form No. 5 — Serial No. 90

FOUNDRY REPORT OF HEAT MAD July 1, 191 4

MATERIALS USED IN HEAT					PRODUCT OF HEAT.					
METALS	WEIGHT	UNIT PRICE	VALUE	J.O. NO.	NUMBER OF CASTINGS	WEIGHT OF CASTINGS	UNIT PRICE	VALUE	FOUNDRY LOSS	TOTAL VALUE
PIG copper	73	.13429	980	#616 CONNECTICUT	22	70	.12847	899	88	981
PIG tin	32	.3875	1240	#564 NEW YORK	1	50	"	642	63	705
PIG zinc	7	.0634	44	#555 SALEM	4	60	"	771	76	847
PIG Scrap copper pipe	100	.1206	1206	#627 FLORIDA	3	45	"	578	57	635
				#394 NEW YORK	1	80	"	1028	100	1128
SCRAP	154	.08	1232	SCRAP (CHARGE TO CLASS 69)		50	.08	400		400
				FOUNDRY LOSS		11				
TOTAL	366		4702	TOTAL		366		4318	384	4702.

CHARGED 366 — NUMBER OF GOOD CASTINGS SUBMITTED 366 — WEIGHT OF GOOD CASTINGS 305 — FOUNDRY LOSS 1.43 — AVERAGE OR CHARGING PRICE PER LB .12847 — DIFFERENCE IN PRICE BETWEEN METAL & SCRAP 2.43 — TOTAL 5.84 — COST PER LB. .01.54

CHARCOAL
COKE
SAND
FUEL OIL
TOTAL

Exhibit "B".

E. A. Schilling — IN CHARGE OF FOUNDRY

ENTRIES & CHARGES MADE BY

date set for completion, etc. A sample of a work request from a ship; a sample copy of the job order issued; a sample of the job order "brief" issued to the shops; a copy of the receipt obtained on delivery; also, a copy of the material stubs used, are hereto attached. Exhibits "A," "B;" "C^1" (front view), "C^2" and "C^3" (back of "C^1" as rendered by different shops); "D;" "E^1," "E^2," "E^3" and "F." Finally all papers concerned are filed in a large envelope for reference.

Photographs of parts of the shops are shown in cuts.

THE FOUNDRY USE OF NON-FERROUS SCRAP METALS.

By Lieutenant F. M. Perkins, U. S. N., Member.

The following method of using non-ferrous scrap metals at the Puget Sound Navy Yard is the result of some three years of attention to the subject and has proved to be very satisfactory.

Little of originality is claimed for the method or for the principle upon which it is based. It is, in fact, about the only logical way in which to handle the scrap question and one which soon suggests itself to anyone interested in foundry work and is, undoubtedly, now in general use to a certain extent. The following is, therefore, simply a description of a systematic and orderly method of applying an old idea together with some data illustrative of the results of the method.

The primary object of using scrap metals in the foundry is a reduction in the cost of castings, and this must be obtained without a reduction in the quality. These two considerations are not incompatible; they are, on the contrary, complementary when the scrap is properly used.

Before attempting to outline a method of using scrap it may be well to illustrate by a little simple arithmetic the extent of the saving which may be effected by the proper use of scrap. Take scrap gun bronze for example; its composition will be approximately:

	Per cent.
Copper,	88
Tin,	10
Zinc,	2

Now if this scrap gun bronze is not used in the further manufacture of gun bronze, but, through lack of knowledge of its composition or through belief that good bronze cannot be

made from scrap, it is used in the manufacture of some lower-grade alloy, say cast naval brass, we shall have the gun-bronze mixture substituted for an alloy which is only required to be up to the following standard:

	Per cent.
Copper,	62.00
Tin,	0.05
Zinc,	37.95

The loss due to the substitution of the high-grade scrap for naval (yellow) brass is equal to the actual difference in value between the metals composing the two alloys. Let us figure, for example, what the loss would be if 100 pounds of scrap gun bronze were substituted for 100 pounds of naval brass.

*Value of 100 Pounds of Gun Bronze.**

Copper, 88 pounds at $0.16,	$14.08
Tin, 10 pounds at $0.35,	3.50
Zinc, 2 pounds at $0.06,	.12
Total,	$17.70

Value of 100 Pounds of Naval Brass.

Copper, 62 pounds at $0.16,	$9.92
Tin, .05 pound at $0.35,	.02
Zinc, 37.95 pounds at $0.06,	2.28
Total,	$12.22

The difference in value is $5.48 per hundred pounds, or about 5½ cents per pound; or, in other words, gun bronze is worth about 45 per cent. more than naval brass. It is quite apparent that good gun-bronze scrap should not be used for making naval brass.

The loss due to the excess of copper could be eliminated by the addition of zinc and lead in sufficient amounts to reduce

* Prices of these metals are, of course, subject to fluctuations; these are representative of the average.

the scrap gun bronze to the approximate composition of naval brass. The tin, however, which is by far the most valuable component, would cause a considerable loss, as the naval-brass mixture requires practically no tin. Another great objection to this method is that if both scrap gun bronze and scrap yellow brass were to be used in the production of yellow-brass castings the supply of scrap for this purpose would exceed the demand. Furthermore, it is not good practice nor is it economical to take high-grade gun-bronze scrap and convert it to yellow brass by the addition of zinc, and this is due to the fact that the gun bronze is much more free from impurities than yellow brass. Its use in this manner is, therefore, wasteful. It is like putting a four-dollar man on a two-dollar job.

Gun bronze and naval brass have been taken as an illustration; the foregoing remarks apply also to several other high copper-bearing alloys related to gun bronze and several comparatively low copper-bearing alloys related to naval brass.

The method in most common use and the one recommended is, briefly, to segregate the scrap according to composition, to melt it in large quantities, to obtain homogeneous lots, to pig it, analyze it and to use it, with the proper additions of virgin metals, in the manufacture of the alloy which it most nearly approximates. This method, properly applied, has no apparent ill effects upon the alloys, but, on the contrary, seems to improve their physical properties and casting qualities.

The first and a most essential point is the careful segregation of the scrap according to composition. The scrap is delivered to bins built alongside the yard railroad track within a few yards of the foundry. Separate bins are provided for the stowage of scrap copper, zinc, lead, gun bronze, phosphor bronze, manganese bronze, yellow brass, and separate bins for the borings and turnings of each kind. Metallic-packing scrap is stowed in the foundry and babbitt scrap is kept in the machine shop on the babbitting floor. Non-ferrous scrap coming off ships under repair is delivered in cars to the bins. Here the master molder, or a leading man, looks over the scrap

and supervises its distribution into the various bins. It is a comparatively easy matter for an experienced and intelligent molder to properly separate the scrap. From the nature of the casting he can tell of what composition it was originally made and can also readily determine by the color whether it is yellow brass or "red brass." The latter term applies to high copper-bearing alloys such as gun, valve and phosphor bronze. No trouble has been experienced in properly classifying scrap of this nature. Scrap castings containing pieces of iron or steel, such as bolts, nuts, studs, etc., are thrown to one side and the iron or steel removed before placing the scrap in the bins. Copper pipe is first taken to the blacksmith shop, placed under a hammer and flattened and then cut in the shears into convenient lengths for charging. Heavy copper-wire condenser tubes, long pieces of sheet copper, sheet brass, etc., are also cut in the shears to convenient lengths. Light sheet copper and light copper wire are heated in an open wood fire and tamped into shape for charging. Heavy castings which are too large for charging are heated and broken up with a sledge or the drop.

The proper segregation of scrap borings and turnings must commence in the machine shop where they accumulate. A removable pan for receiving borings and turnings is placed under each machine. The leadingmen are held responsible for seeing that the pan is changed or emptied when the kind of material to be worked on in the machine is changed. Several stations are provided for receiving the borings and turnings, each station having several labelled boxes capable of holding several days' accumulation of the various kinds of turnings. The turnings are collected about twice a week, run through a magnetic separator to rid them of what iron and steel have found their way in, and then delivered in the boxes to the foundry bins.

In handling borings and turnings special care is taken to guard against the introduction of iron or steel filings, drillings, turnings, etc. Sweepers are not allowed to use the scrap boxes for receptacles for their sweepings, as these always contain

iron and steel filings and dust. Too much must not be left to the magnetic separator; it removes a large proportion of the iron and steel, but not all. The borings and turnings from babbitt and metallic packing also require care in handling; these metals are expensive and in this form are easily spoiled. Little chips of iron and brass will not melt down when these white metals are remelted, and they form hard spots which will score a rod or journal. Brass borings in particular must be kept out of white metals for, of course, they cannot be removed by the magnetic separator. Metallic packing and babbitt must not be allowed to become mixed; the two metals are difficult to distinguish by sight and are usually of widely differing composition.

A little care in the machine shop will pay big dividends in the foundry in the form of increased purity and consequent increased value of the scrap. A handful of iron will ruin a hundred pounds of babbitt.

As the various scrap metals accumulate in sufficient quantities in the foundry bins they are pigged; the cost of pigging and the melting loss being charged to title Z orders issued upon request of the general storekeeper. These charges are prorated on the metal pigged on a per pound basis. Scrap metals are pigged in large quantities (about 25,000 pounds and over) at a cost of about ¼ cent per pound plus the melting loss. This loss varies considerably with different grades of scrap, and will run from two or three per cent. in alloys containing little or no zinc to eight or nine per cent. in alloys high in zinc.

In figuring the actual money loss due to volatilization, furnace loss or "shrinkage," as it is variously called, it should be remembered that, in the case of metals high in zinc, the metal which is lost is not of the same composition as the alloy being melted, but contains relatively a much higher amount of zinc. As zinc is the cheapest metal found to any extent in the brasses this reduces the actual money loss to considerably less than the percentage of loss by weight would seem to indicate. For example: Suppose that in melting 100 pounds of yellow

brass containing copper 60 per cent., zinc 40 per cent., valued at $12.00, or 12 cents per pound, the melting loss amounts to 8 per cent., or 8 pounds. The actual loss then is not 8 per cent. of $12.00, or $0.96, but approximately 6 pounds of zinc at $0.06 per pound plus 2 pounds of copper at $0.16 per pound, or $0.68. Thus, while the melting loss by weight amounts to 8 per cent. the actual loss in money is only 5.7 per cent. This difference is not at present considered in accounting. In the case of melting scrap for pigging the loss by weight is never actually as great as the weights of a given amount of metal before and after pigging would seem to indicate. Nearly all scrap contains a certain amount of non-metallic foreign material of no value, in the form of dirt, oil, grease, sand, insulating materials, etc. In certain kinds of scrap this may form quite an appreciable amount, and the cheapest and most practicable way to remove it is by fluxing it out in melting.

The primary object of pigging scrap is to reduce it to lots of homogeneous and known composition so that it can be intelligently used in the manufacture of castings. That the actual saving in dollars and cents far outweighs the cost of pigging will hardly be disputed by anyone who has had practical experience with the foundry-scrap question. Beside the direct saving there are other practical benefits resulting from pigging and melting, by analysis, namely:

1. The metal will be used for the purpose for which it is best suited.
2. A more uniform grade of castings can be produced.
3. It affords an opportunity to cast test pieces for determining the physical properties and casting qualities of the metal before it is made into castings.
4. The scrap can be fluxed and cleaned before it is used for castings.
5. Great reduction in stowage space.
6. If records are kept they provide a means for determining the causes of defects and afford valuable data for continuous improvement.

7. It tends toward increased order and system and more scientific melting in the foundry.

There are a few cases wherein the scrap, by its nature, affords most of the information which is ordinarily obtained by pigging, and in such cases there is no need to take the melting loss due to pigging. If a certain large amount of scrap is known to be of homogeneous composition there is no need to pig it. Condenser tubes, for example, form a continuous source of scrap of unvarying composition, and for this reason should be stowed separately. A large bronze propeller or any other large, single casting can be broken up, a sample taken and analyzed, and the metal used to the best advantage without being pigged. Such cases, however, form but a small percentage of the total amount of scrap.

Copper pipe is a very valuable and highly prized form of copper scrap and is used without pigging. It is made of a high grade of copper (99.5 per cent. pure) and, either alone or mixed with virgin ingot, produces excellent brass and bronze castings. Scrap lead, if clean, is used directly; if dirty it is melted and cleaned. The two principal sources of scrap zinc are old hull zincs and the trimmings, cuttings and drillings from new zinc. The former contain a very large amount of dross while the latter are very pure. The old zinc is run down and the dross skimmed off; the new zinc is used directly.

The scrap, having been properly separated and prepared for charging, is melted in a two-ton, oil-fired Hawley-Schwartz furnace in lots of from 3,000 to 5,000 pounds, the capacity of the furnace depending largely upon the shape and density of the scrap. As much care is exercised in the melting of the scrap as in the melting of metal to be used directly in the molds, and this point is of great importance. A charge of a few hundred pounds of scrap and two or three pounds of charcoal is first placed in the pre-heated furnace and the heat turned on. When this charge begins to melt down the molten metal is covered with a heavy layer of charcoal and the remainder of the scrap is charged. The molten metal in the

bottom of the furnace, with its covering of charcoal, forms a bath into which the metal runs as it melts down.

The function of the charcoal is to prevent oxidation of the metal. Oxidation or burning of the metal, in addition to causing a high furnace loss, produces blow-holes, due to absorption of the oxide in the metal and flaws due to the mechanical inclusion of the hardened metallic oxide.

When molten metal is exposed to the air a film of oxide forms upon the exposed surface, the depth of the film and the rapidity of formation depending somewhat upon the temperature, but primarily upon the affinity of the metal for oxygen. This film, when cooled slightly, becomes a hard scale, and if allowed to enter the mold produces flaws in the casting.

Of all the metals used in the brass foundry copper has the greatest affinity for oxygen and it is also the most widely used; hence the necessity for a working knowledge of oxidation and its prevention.

Charcoal reduces oxidation by forming a covering over the molten metal and thereby excluding air. It also reduces the absorption by the metal of the sulphur in the fuel. All the fuels used in brass melting (coal, coke and oil) contain sulphur, which should not be allowed to enter the brass. Charcoal contains no sulphur, but is too expensive to be used as a fuel except in unusual cases.

In order that the charcoal may properly serve its purpose it should be broken up in small pieces; the smaller the pieces that can be used in a furnace or crucible without being blown out by the blast the greater will be the protection to the metal and the less the expenditure of charcoal.

A flux of borax, rock salt or glass is used to fuse with the dirt and impurities in the scrap and form a slag on the surface of the metal, which is later skimmed off. The amount of flux to be used depends upon the cleanliness of the scrap and upon the amount of zinc contained in the metal, high zinc metals requiring more flux.

The molten scrap is poured into a 1,000-pound ladle swung from the crane, and from this ladle is poured into a reversible

FIG. 1.—REVERSIBLE MOLD FOR CASTING SCRAP BRASS AT FOUNDRY.

FIG. 2.—REMELTED SCRAP BRASS AT FOUNDRY (ABOUT 110 TONS).

ingot mold having a capacity of twenty ingots of about forty pounds each. Fig. 1 shows the ingot mold, and in the background of the same figure is the furnace used for melting the scrap. After the furnace is well heated 4,000 pounds of metal can be melted in 45 minutes and cast into ingots in about 30 minutes.

The metal is thoroughly stirred in the furnace and again stirred and fluxed with borax in the ladle and skimmed before being poured into the ingot molds. Thorough stirring, both in the furnace and ladle, is of the greatest importance, as it insures uniformity of composition of the entire heat. The serial number of the heat is then stamped on each ingot for purposes of identification and to prevent the possibility of lots becoming mixed. The various lots are then stowed separately in bins with the serial number of each lot posted on the bin containing it. Figure 2 shows about 100 tons of pigged scrap stamped and ready for stowage in the bins, which are about twenty feet away, but not shown in the picture. The picture gives a good idea of the great saving in stowage space due to pigging.

Standard test pieces are cast, and these and a mixture of drillings from three ingots are sent to the chemist for determination of the composition, tensile strength and elongation. The chemist forwards his results to the shop superintendent, who determines from the data what alloy the scrap is best suited for and computes the amount of new material to be added to the scrap to bring it up to the desired composition.

These results are entered on the "Scrap-Metal Record" card forwarded to the master molder, who files the cards for reference when using the scrap.

Fig. 3 shows this card with entries for a heat of scrap valves and pressure castings. It will be noticed that the card also shows the analysis, tensile strength, elongation and melting loss. The scrap is used in the foundry in accordance with the instructions on the card, and in one or more heats for each lot of scrap used test bars are taken, and the tensile strength, elongation and chemical analysis of the metal after

recasting are entered on the back of the card. The comparison of the properties of the metal before and after being "sweetened up" with virgin metal affords interesting and valuable information. A little experience will enable one to accurately control the composition of the brass-foundry products and to predict very closely what the properties of a given lot of scrap will be when corrected and made into castings. The card gives a fairly complete record for practical foundry purposes and enables the foundryman to do his melting scientifically, accurately and without guess-work.

SCRAP METAL RECORD

HEAT NO	DATE	KIND OF SCRAP MELTED
20	11/19/14	Comp. G - Heavy Fabrics and pressure Castings.

CHARGED	RECOVERED	LBS. LOSS	PER CENT LOSS
4800	4695	105	2.2

ANALYSIS

Copper	86.64	Antimony		TENSILE STRNGTH	41750
Tin	8.87	Manganese			
Lead	0.64	Phosphorus		ELONGATION	6.75
Zinc	4.05	Iron	Trace.		

This Scrap is best suited for Comp. G - Gun Bronze

To obtain same, add the following to each 100 lbs. of ingot:

COPPER	TIN	PHOS. TIN	LEAD	ZINC	ANTIMONY		
78	8½	1½	—	—	—		

FIG. 3.

A careful study and conscientious use of such records and a little study of the principles of furnace and crucible operation will soon permit one to use a considerable percentage of scrap and to improve the quality of the metal at the same time. All that is required of the melter are average intelligence and absolute obedience in following instructions. Many melters like to surround their operations with mystery, and some of them have their own brand of jealousy-guarded "dope" which they introduce into the ladle and whose principal effect is to

create a large cloud of smoke and many admiring glances from the helpers and apprentice boys. While experience in a melter is desirable it is not essential. Under proper supervision any intelligent, willing man interested in learning can be made into a first-class brass melter in three months.

The principal points to be cared for in good practice are care in the preparation of the scrap, adherence to the specifications governing the composition of the metal, and the observance of a few well-known principles of melting. The most essential of these principles are:

1. Protection of the metal from oxidation during melting. This is ordinarily accomplished mechanically by covering the bath with charcoal or by otherwise preventing the flame and air from coming in direct contact with the metal, as by the use of covered crucibles.

2. Deoxidation of the metal after melting. Oxidation cannot be entirely prevented during melting. After melting it can be deoxidized chemically to a certain extent by the addition of some substance having a greater affinity for oxygen than the alloy. One of the best agents for this purpose is from .75 per cent. to 1 per cent. of phosphor tin (a mixture containing 95 per cent. tin, 5 per cent. phosphorus). Phosphor copper is used when the metal to be deoxidized does not contain tin. As phosphor copper contains 10 per cent. phosphorus only half as much need be used. It is a mistake to assume that the more phosphorus is introduced the cleaner the metal will be. If the proper amount is used it will take up the oxygen and pass off as gas and the metal will show barely a trace of phosphorus or none at all. If too much is used only that which combines with the oxygen will pass off and the remainder will remain in the metal and cause blowholes.

3. Melting the metals in the inverse order of their fusibility and volatility, *i. e.*, melting that metal first which is the least volatile and has the highest melting point. There are a few metals which are more volatile than others having a lower melting point and, in order to reduce the melting loss, the

volatility should, in such cases, be the first and fusibility the second consideration. Zinc is the most common example of this met with in foundry practice; it has a higher melting point than tin or lead but is much more volatile than either and is added last.

4. Thorough mixture of the metal composing the alloy. This is accomplished mechanically by means of a stirring rod used in the furnace and also in the ladle. As each new metal is added it should be thoroughly stirred as soon as it has run down. The last operation before pouring the mold should be to stir the metal and, in case of the white-metal alloys, it will be found beneficial to continue gently stirring the metal in the ladle during pouring. A metal which has been found to contain pin-holes, blow-holes or flaws can often be made perfectly good simply by remelting.

5. Pouring the metal at the proper temperature. This is important but one of the most difficult points to control. The proper temperatures of pouring must first be known and some quick and reliable method of measuring them must be provided. Correct casting temperatures have been determined for a few metals but not for the majority of them. A scientific investigation of the melting temperature and casting temperature upon the principal alloys would be of the greatest value. The main points to be covered would be the effects upon strength, elasticity, hardness and soundness. The alloys investigated should not be chemically pure, but should contain the impurities to the extent ordinarily found in actual practice. The metal should not be overheated and allowed to cool; this practice increases the furnace loss and produces inferior castings. The metal should be removed from the furnace when the proper temperature is reached and poured into the molds as soon as possible. In general, the brasses and bronzes should be poured hot and cooled quickly; rapid cooling or quenching has the opposite effect upon brasses to that produced by the same means upon iron. Rapid cooling or chilling a brass or bronze casting increases its strength and decreases its hardness. Various makes of electrical and op-

tical pyrometers are on the market for determining the temperatures of molten brass. A great many of them are inaccurate or unpractical. Investigation to determine the best pyrometer for brass-foundry use would be of value after proper casting temperatures had been determined.

6. Removal of dirt, dross and foreign matter by the use of suitable fluxes. The fluxing material—borax, salt or salammoniac—is thrown upon the surface of the metal in the ladle and well stirred in. The resulting dross or slag which forms on the surface is then skimmed off.

It has been found from experience that a very high percentage of scrap can be used if it is clean and well suited to the alloy in which it is used. In fact, high-grade scrap alone with the addition of sufficient zinc to replace the loss due to volatilization will often make excellent castings entirely complying with the chemical and physical requirements of the specifications. To take proper advantage of such high-grade scrap it is necessary that the method of pigging and melting by analysis be followed. In the case of the high copper-bearing alloys (gun bronze, phosphor bronze, valve bronze, etc.), the greatest difficulty encountered in the use of scrap is to keep the iron at the very low point required by the specifications, hence the necessity, previously mentioned, of taking every precaution to remove iron from scrap castings and to prevent it being mixed with borings and turnings. Lead also gives trouble and will be referred to later.

In order to reduce the relative amount of iron it is often necessary to add considerably more new metal to a given amount of scrap than would be required if the scrap contained less iron. Experience would seem to indicate that the allowable percentage of iron could be increased without detriment to the metal. The presence of a small amount of iron in gun, valve and phosphor bronze within certain limits seems to cause a slight increase in tensile strength and a slight decrease in elongation. As the amount of iron is increased the tensile strength and elongation decrease. This statement is not based upon accurate, scientific experiment, but upon data collected

in the ordinary course of foundry operation. It would be interesting, instructive and of actual value to determine by exact laboratory methods the actual effect of varying percentages of iron upon several of the bronzes with the object of increasing the allowable maximum if found advisable.

The following table shows the composition, tensile strength and elongation of five heats of scrap containing iron:

Heat No.	Cu.	Sn.	Zn.	Pb.	Fe.	T. S.	Per cent. elong.
1	87.02	8.65	3.94	0.15	0.24	39,000	8.6
2	86.64	7.90	4.56	0.69	0.21	42,550	10.5
3	85.92	7.90	5.30	0.75	0.13	39,475	7.8
4	85.60	6.78	5.97	1.65	Trace.	27,730	14.0
5	71.88	1.57	25.93	0.28	0.34	31,100	18.8

Numbers 1, 2 and 3 are suitable for conversion to gun, valve or phosphor bronze, but, on account of the comparatively large amounts of iron in the scrap, it will be necessary to add an excessive amount of new metal to reduce the percentage of iron to the point required by the specifications. Therefore, the scrap will form but a small percentage of the total melt and the saving due to its use will be comparatively small. Number 4 contains only a trace of iron but is rather high in lead and zinc. The addition of 59 pounds of copper, 7 pounds of tin and 1 of phosphor tin as a deoxidizer to the number 4 scrap will convert it into good valve bronze, the above amounts being added to 100 pounds of the scrap. In this case the resulting metal will contain 60 per cent. of scrap, and the saving due to its use will be considerable. This illustrates the necessity of keeping iron out of brass scrap and shows the saving that can be effected thereby. Number 5 is too high in zinc to be suitable for anything but yellow brass and should be converted to such by the addition of proper amounts of lead and zinc.

The following table shows the composition, tensile strength and elongation of thirteen heats of gun and valve bronze which contain, on the average, about 50 per cent. of new metal and 50 per cent. of scrap.

Heat No.	Cu.	Sn.	Zn.	Pb.	T. S.	Per cent. elong.
1	86.64	9.38	3.03	0.95	35,240	24.2
2	87.51	8.75	3.64	0.10	38,610	25.0
3	87.26	8.33	4.01	0.40	34,240	19.5
4	86.72	8.80	3.59	0.89	39,400	18.75
5	88.42	8.76	2.32	0.50	38,700	21.9
6	88.36	7.67	3.24	0.48	36,260	25.0
7	87.28	7.28	4.01	1.43	34,370	18.75
8	89.03	7.67	2.49	0.81	36,480	25.0
9	87.85	7.56	4.09	0.50	32,630	15.6
10	88.59	7.61	3.21	0.59	35,400	20.3
11	88.39	7.45	3.55	0.61	34,370	18.75
12	88.26	7.37	3.75	0.62	34,870	18.75
13	88.11	8.02	2.98	0.89	35,240	20.3

In only one heat are the specifications complied with (No. 2) for gun bronze in so far as the lead content is concerned (not over 0.20 per cent.). The others meet the specifications for valve bronze. The tensile strength and elongation are, however, uniformly excellent and in every case exceed the requirements of gun bronze.

The following table shows the results obtained from eight heats of gun bronze made entirely from first-grade ingot (new) metal:

Heat No.	Cu.	Sn.	Zn.	Pb.	T. S.	Per cent. elong.
1	87.36	10.01	2.54	0.09	30,940	10.1
2	87.44	10.24	2.22	0.10	33,100	11.7
3	87.45	10.17	2.22	0.16	32,770	12.5
4	87.20	10.37	2.32	0.07	30,920	10.9
5	87.20	11.00	1.64	0.16	31,460	8.6
6	86.59	10.87	2.47	0.07	31,380	9.4
7	87.70	10.21	2.06	0.03	34,370	14.1
8	87.20	9.73	3.03	0.04	31,520	12.5

Note that the requirements of the specifications are not met as regards elongation. This is not offered as proof that 15 per cent. or more of elongation cannot be obtained in gun bronze, for by careful melting this percentage can be obtained. Comparison of the two preceding tables does show, however, that for the same melting practice better metal can be made by the proper use of good scrap comparatively free from impurities. The scrap should be of the approximate composi-

tion of the alloy being made and may be used to advantage in amounts varying from 10 per cent. to 60 per cent. It has been found that, when properly used, scrap not only improves the strength and elasticity but the soundness of the castings as well, and soundness is often the primary consideration. The writer has talked over this matter with a number of foundry foremen, and in each case his own experience has been confirmed, *i. e.*, that it is possible to produce better castings when a certain amount of good scrap is used. The explanation of this probably lies in the fact that pure copper absorbs oxygen and certain gaseous products to a much greater extent than an alloy which results in an increased porosity. This a well-known fact to which the great difficulty of obtaining sound copper castings bears evidence.

It is a difficult matter to obtain scrap in very large quantities sufficiently free from lead for use in alloys where the maximum amount allowed is 0.20 per cent. The elimination of iron is largely a matter of care in handling the scrap, but lead is not so easily removed. In the above table it will be noticed that the lead runs as high as 0.16 per cent. when no scrap is used. This is due to its being contained as an impurity in the other metals.

Foundry results appear to indicate that the amount of lead could be increased with benefit to gun bronze and number one phosphor bronze, in that it would permit a wider use of scrap with the beneficial results before noted, at the same time reducing very materially the cost of the metal.

The general effect of small quantities of lead upon the brasses and bronze is to decrease the hardness and increase the density. In other words, machining qualities are improved and porosity is decreased. Lead is used in valves and pressure castings to make them "close," *i. e.*, to decrease the porosity. Too much lead reduces the strength, but the amount of lead that can be added without a material reduction in strength is fairly high. There are commercial valves, for example, made of valve metal containing 3 per cent. lead and

having a tensile strength of 30,000 pounds and an elongation of 20 per cent.

As previously mentioned when considering the effect of iron, the foregoing tables and discussion concerning lead are not based upon scientific experiment, but upon observations made and data collected in the ordinary course of foundry operation.

John Dewrance, in a paper entitled "Bronze," read before the Institute of Metals and later published in "Engineering" and republished in the JOURNAL OF THE A. S. N. E. for May, 1914, furnishes some very interesting information concerning the effects of lead upon gun bronze tested at different temperatures. He found that straight gun bronze (88–10–2) dropped from a tensile strength of about 32,500 at 350 degrees F. to 19,000 pounds at 400 degrees F. Upon substituting ½ per cent. of lead for an equal amount of copper (giving 87½, 10, 2, ½) he found that the strength of the bronze remained at about 32,000 pounds up to a temperature 550 degrees F., above which it rapidly decreased to 22,500 pounds at 600 degrees F. The variation in elongation he found to be even more pronounced; at 550 degrees F. the alloy containing ½ per cent. lead gave an elongation of 18 per cent., and the straight gun bronze at the same temperature gave an elongation of a trifle less than 2 per cent.

In gun bronze to which had been added 10 per cent. of lead at the expense of the copper was found a strength of 28,500 pounds and an elongation of 10 per cent., and when the amount of lead was increased to 16 per cent. the alloy still had a strength of 25,000 pounds and elongation of 5 per cent. This test was made with the metal heated at 500 degrees F.

In considering these results it should be borne in mind that lead softens the brasses, and therefore a casting which is to be subject to great erosive action should contain but very little lead.

The most authoritative writers on the subject of alloys have usually investigated pure alloys and have taken particular care to see that impurities were eliminated. For this reason

reliable information of an exact nature as to the effects of impurities upon brasses and bronzes is very scarce. It is believed that careful investigation of the effects of the use of scrap and of varying amounts of lead and iron in certain alloys used in the Navy would corroborate results obtained in the foundry and disclose information which would warrant a wider use of scrap in the higher-grade alloys.

THE GAUSS GRAPHIC METHOD OF REPRESENTING LENSES AND TELESCOPES.

By Lieutenant F. J. Cleary, U. S. Navy, Member.

The exact mathematical calculations required in designing lenses are complicated and extensive, especially in new construction, the optical layout of a new design of telescope covering a dozen or more pages of logarithmic work.

The formulae used and the resulting calculations are so technical in character that their presentation here is not warranted.

There is, however, a graphic method of lens calculation which is so simple and which illustrates so clearly the relations existing in a telescope system between angle of field of the instrument, angle of field of the eye piece, magnification, aperture of the objective lens, exit pupil, focal lengths of objective lens and eye piece, and the relative positions of the various lenses and the images formed, that it is believed that a description of this graphic method will be of interest to the naval service.

This method of lens representation is due to C. F. Gauss, one of the foremost German mathematicians and opticians, and consists of substituting for the curved-lens surfaces a series of planes normal to the central axis.

A few preliminary definitions and explanations are necessary.

A *lens* is a portion of a refracting medium bounded by two surfaces of revolution called *faces*. The face that is presented to the source of light will be called the *first face*. The other face will be called the *second face*. The lenses with which we have to deal are made of glass, and the faces are either both spherical or one face plane and the other spherical.

The *principal axis* of a lens with two spherical faces is the straight line joining the centers of curvature of its faces. In a lens that has one plane face, the principal axis is the normal to the plane surface that passes through the center of curvature of the spherical face.

The points where the principal axis cuts the faces of the lens are called *poles*.

The distance between the two faces measured along the axis is the *thickness* of the lens.

Lenses are divided into two general classes:

First, those that can form real images, called convergent, positive or collective lenses. They are generally thicker in the middle than at the edges.

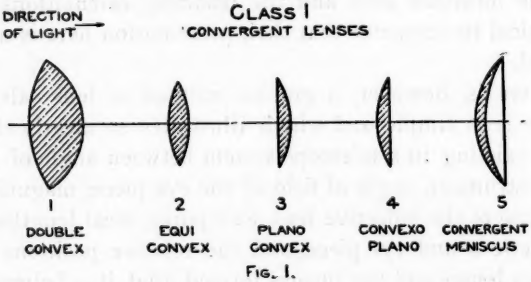


FIG. 1.

Second, those that, when situated in a medium less dense than the lens, can form only virtual images. Such lenses are called divergent, negative or dispersive lenses. They are generally thinner in the middle than at the edges.

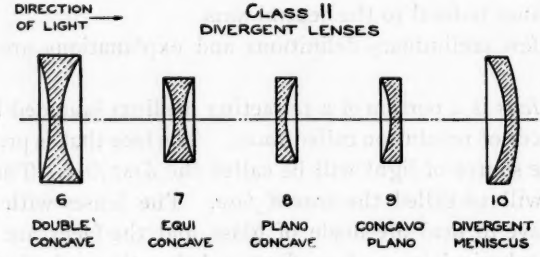


FIG 2.

The *optical center* of the lens is the point of intersection on the axis made by any ray whose direction after emergence is parallel to its direction before entering.

The *first principal point* is the focus on the axis *conjugate* to the optical center by refraction through the first face alone.

The *second principal point* is the focus on the axis conjugate to the optical center by refraction through the second face alone.

The first and second principal points may also be defined as the points on the axis intercepted by the prolongations of the entering and emergent directions of a ray of light passing through the optical center.

The *equivalent thickness* is the distance between the first and the second principal points measured on the axis.

These definitions are illustrated by Figs. 3 and 4.

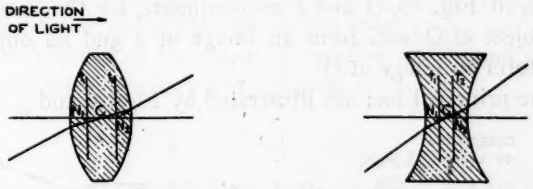


FIG. 3. FIG. 4

C is the optical center; N_1 and N_2 are the first and second principal points; p_1 and p_2 are the first and second principal planes; N_1N_2 is the equivalent thickness. Where the faces of the lens are not of the same curvature the principal planes are displaced toward the face having the greatest curvature (least radius of curvature). Where one face is plane, one principal plane always lies tangent to the curved face, the other principal plane lying within the lens. In meniscus lenses one principal plane always lies outside of the lens. If the meniscus is deep enough both planes will lie outside the lens (Fig. 5).

The *first principal focus* (f_1) of the lens is the focus on its axis conjugate to a point at an infinite distance in rear of the lens.

The *second principal focus* (f_2) of a lens is the focus on its axis conjugate to a point at an infinite distance in front of the lens.

Fig. 5.

The term "conjugate" is used in optics to express the relationship between two mutually interchangeable factors.

For example, in Fig. 6, f_1 and a point at an infinite distance in rear of the lens are conjugate for the reason that rays of light from a source at f_1 will intersect at infinity, and all rays of light from a source at infinity will intersect at f_1. Similarly, in Fig. 16, O and I are conjugate, for the reason that an object at O will form an image at I and an object at I will form an image at O.

The principal foci are illustrated by Figs. 6 and 7.

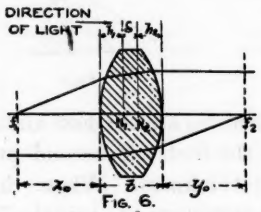


Fig. 6.

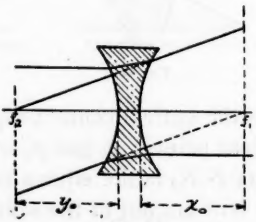


Fig. 7.

f_1 and f_2 are the first and second principal foci. The planes through the foci normal to axis are, respectively, the first and second focal planes.

Where the faces of the lens are of equal curvature the distance between the first principal focus and the first principal point is equal to the distance between the second principal focus and the second principal point. This distance is called the focal length. Where the curvature of the two faces is not the same the focal lengths of the lens are not equal.

The principal use of the principal planes is derived from the property that the prolongation of both the incident and the refracted rays cuts the principal planes at the same distance from the axis. If we know the equivalent thickness and the focal lengths of a lens the lens may be represented by the principal planes only, and a graphic solution may be worked out for a lens or a series of lenses. The proof of this method will be given at the end of this article.

The equivalent thickness (δ) and the focal length(f) can be obtained as follows:

In Fig. 6,

Let

h_1 be the distance of the first principal point (N_1) from the first face;

h_2 be the distance of the second principal point (N_2) from the second face;

t be the thickness of the lens on the axis;

$r_1 r_2$ be the radii of curvature of the first and second faces;

μ be the refractive index of the glass;

Then

$$\delta = t - (h_1 + h_2).$$

The values of h_1 and h_2 for a double convex lens are:

$$h_1 = \frac{tr_1}{\mu(r_1 + r_2) - t(\mu - 1)};$$

$$h_2 = \frac{tr_2}{\mu(r_2 + r_1) - t(\mu - 1)};$$

And

$$\delta = t - \frac{t(r_1 + r_2)}{\mu(r_1 + r_2) - t(\mu - 1)}. \quad . \quad . \quad . \quad (1)$$

If x_0 is the distance from the first principal focus to the first face,

y_0 the distance from the second principal focus to the second face,

then from the definition of focal length given above

$$f = x_0 + h_1 = y_0 + h_2,$$

and we have the formula

$$\frac{1}{f} = p = (\mu - 1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right) - \frac{t(\mu - 1)^2}{\mu r_1 r_2}.$$

For practical purposes the thickness (t) of the lens may be disregarded and the formula becomes

$$\frac{1}{f} = p = (\mu - 1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right).$$

The following numerical example is given:

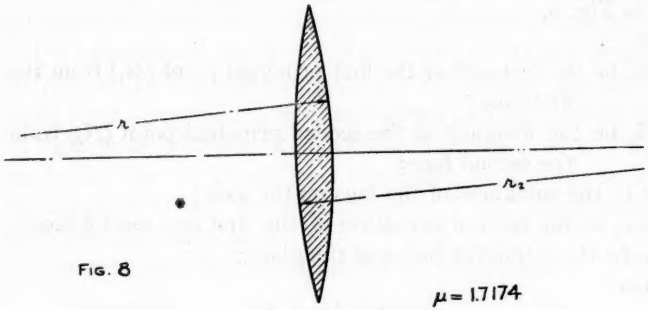


FIG. 8

$$\frac{1}{f} = p = .7174 \times \left(\frac{1}{.2} + \frac{1}{.2}\right) = 7.17.$$

$$f = \frac{1}{7.17} \text{ meters} = 139.4 \text{ millimeters.}$$

The term "p" in the above formulae is known as the *power*. This must not be confused with *magnifying power* or *magnification*, as the terms have entirely different meanings.

The *power* of a lens is its ability to change the curvature of the advancing front of a wave of light.

The *power* of a lens is the reciprocal of its focal length. The international unit of power is the dioptrie. The power of a lens in dioptries is the reciprocal of its focal length in meters.

Fig. 9 shows the graphic solution of a lens (or a lens equivalent to a compound lens) where the focal lengths and the equivalent thickness are known.

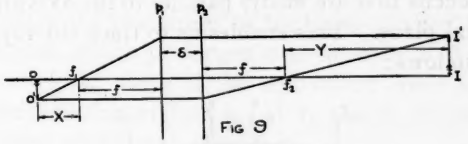


Fig 9

p_1 and p_2 are the principal planes, f_1 and f_2 are the first and second principal foci, and OO^1 is the object at a distance X from f_1. If we take the point O^1 on the object and draw a ray parallel to the axis we know from the definition of principal foci that this ray will pass through f_2, the second principal focus. We know also that a ray drawn from O^1 through f_1, the first principal focus, will emerge parallel to the axis, and therefore the intersection of these two rays at I^1 will give a point of the image conjugate to O^1, and an image, real and inverted will be formed at II^1. The distance Y of this image from the second focal point is given by the very simple relation

$$XY = f^2.$$

This equation shows that when $X = \infty$, $Y = o$ and conversely, which we know to be true from the definition of the principal foci. Also if X is large, say one mile, then Y is so small as to be inappreciable. Hence, any pencils of light from a distant object can be regarded as parallel pencils.

An approximate value of the magnification of a lens in the above terms is given by

$$M = \frac{f}{X}.$$

Another property of lenses is that parallel pencils that are not vertically incident, but make a small angle with the axis come to a focus in the focal plane.

COMBINATION OF LENSES.

The effect of combining lenses may be determined by using the principal planes, and the theory, already stated, that parallel pencils that are nearly parallel to the axis are focused on the focal plane. This enables us to trace any ray through a lens as follows:

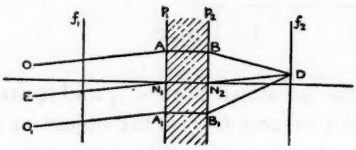


FIG. 10.

p_1 and p_2 are the principal planes, f_1 and f_2 the principal focal planes, and N_1 and N_2 the unit points. Draw OA to represent any ray incident on the first principal plane at A. We know that it emerges at B with AB parallel to the axis. This gives one point B in the prolonged ray and it remains only to obtain one other point. Draw EN_1 parallel to OA. Since this is a central ray, it emerges from N_2 in a direction N_2D parallel to EN_1, and also to OA, since OA is likewise parallel to EN_1. As EN_1 is thus the central ray of a parallel pencil, the pencil will be focused at sone point on f_2. This point is evidently D, where the central ray cuts f_2 and accordingly BD is the emergent direction of the ray OA. In practice it is only necessary to draw N_2D parallel to OA, thus determining the point D.

Similarly, the ray O_1A_1 will likewise pass between the planes parallel to the axis, as shown, and intersect the focal plane f_2 at D.

Fig. 11 shows a combination of two lenses. p_1 p_2 and f_1 f_2 are respectively the first and second principal planes and the first and second focal planes of the first lens. p_1^1 p_2^1 and f_1^1 f_2^1 are the corresponding planes of the second lens.

This combination may be represented by an equivalent lens. The focal planes and the principal planes of the equivalent

lens are obtained by tracing through the combination from each end, a ray entering the system parallel to the axis.

We know that the parallel ray AB from the front passes through the second focal plane of the equivalent lens. Tracing this ray through the two lenses by the Gauss method, the final direction is MG, which prolonged cuts the axis at H, and F_2 is the second focal plane of the equivalent lens; a farther prolongation cuts the original ray at L, and P_2 is the second principal plane of the equivalent lens.

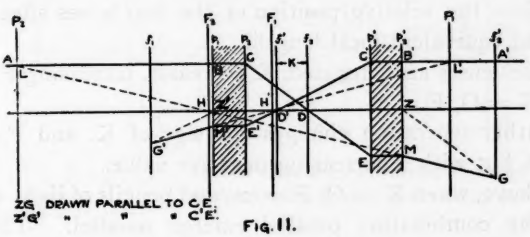


Fig. 11.

(An examination of Fig. 9 shows that in each case the principal plane lies at the point where the original parallel path of the ray is cut by the final path of the ray. This explanation will make clear the location of the principal planes in Fig. 11.)

F_1 and P_1, the first focal plane and first principal plane of the equivalent lens, are found in the same way by tracing the ray A^1B^1, etc., through the system.

The second focal plane (f_2) of the first lens overlaps the first focal plane (f_1^1) of the second lens.

Denote by K the distance between f_1^1 and f_2.

If F is the focal length of the equivalent lens and f and f^1 are the focal lengths of the two lenses, then

$$F = \frac{ff^1}{K}.$$

This equation is capable of mathematical proof, but the proof is not considered necessary in this article.

This formula holds good for any combination of lenses if we observe the conventions that K is positive when f_1^1 is in front of f_2 and that f and f^1 are positive when f_1 and f_1^1 are in front of p_1 and p_1^1 respectively.

F is a real quantity, although it may be either positive or negative.

The formula

$$F = \frac{ff^1}{K}$$

shows how the relative position of the two lenses affects the resultant equivalent focal length.

As the lenses are separated, K decreases, increasing F until when $K = O$, $F = \infty$.

A farther separation changes the sign of K, and F again appears, but with a decreasing negative value.

As above, when $K = O$, $F = \infty$, and pencils of light which enter the combination parallel emerge parallel. This is known as the telescopic condition, as it is found in all telescopes.

In connection with the above discussion of equivalent lenses the following should be borne in mind:

When two lenses having a common axis are separated by a finite distance it is impossible to find a single thin lens which, when placed in any fixed position, will produce an image of the same size and in the same position as that produced by the combination.

A single, thin lens can be found, however, which, when placed at a suitable fixed point, will produce an image of the same size, but not generally in the same position, as that produced by the combination. This is what is understood by an "equivalent lens."

ELEMENTARY TELESCOPE.

Fig. 12 shows two lenses fulfilling the telescopic condition, forming a simple astronomical telescope that produces an inverted image.

p_1 p_2 and p_1^1 p_2^1 are, respectively, the first and second principal planes of the first and second lenses.

F the focal length of the objective lens and f the focal length of the eye piece.

Then F_2 is the common focal plane of both lenses and f_2^1 the second focal plane of the second lens.

θ is the angle of the field.

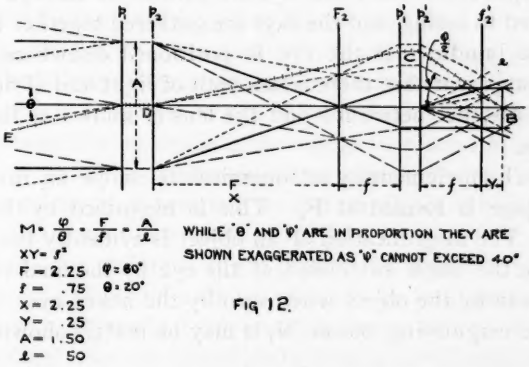


Fig 12.

The paths of parallel pencils are traced out for the vertically-incident central pencil and for two pencils coming from the limits of the field. These three pencils focus as shown, then pass through the second lens and emerge parallel again.

From an examination of this drawing it would seem that the field θ could be enlarged by increasing the diameter of the eye lens (in such case the central ray from one edge of the field being the barred line B, C, D, E), but in practice, the eye piece is limited by spherical aberration to such a diameter that the ange φ is not greater than 40°. In practice, this angle is generally about 35°. A stop is fitted at F_2 of such a diameter that it cuts off all rays outside these limits. The objective is generally made larger than necessary because the lens is more or less imperfect near the edge. Consequently, a larger lens is used, then either partially covered or stopped down at F_2 until the clear aperture is of the proper diameter

to admit the light desired, and to limit the field to prevent spherical aberration.

The figure shows that all these parallel pencils form at *e* an image of the aperture A. This image is a bright spot that may be readily observed on a sheet of paper, held at the proper point, and is called the exit pupil.

To obtain the proper use of a telescope the eye should be at the spot *e*, for there the rays are parallel as the eye is accustomed to seeing, and the rays are gathered together in the smallest bundle. If the eye is positioned elsewhere, it is clearly apparent that there is loss both of light and of field.

The distance between *e* and the lens is known as the eye distance.

In such an elementary astronomical telescope an inverted real image is formed at F_2. This is magnified by the eye piece. The magnification of an object is evidently the ratio between the angle subtended at the eye by the final virtual image and by the object when seen by the naked eye. If we call the magnifying power M, it may be readily shown that

$$M = \frac{F}{f} = \frac{A}{e} = \frac{\varphi}{\theta}.$$

θ is the "apparent field" and

φ is the field of the eye piece.

The field of the eye piece is sometimes called the "true field." This is a confusing term.

As previously stated, the angle φ is limited to from 35° to 40°. Hence, it is apparent that $\theta = \frac{35^\circ}{M}$ and the field is absolutely fixed by the magnifying power.

The expression $M = \frac{F}{f}$ shows that we may increase the magnifying power either by increasing the focal length of the objective (F) or by decreasing the focal length of the eye piece (f).

The expression $M = \frac{A}{e}$ shows that if "e" is fixed at ″.25,

then A = M × ″.25, which gives the clear aperture required, which is less than the diameter of the objective lens. "*e*" always falls in rear of the second focal plane of the eye piece, as it is an image of the aperature of the first lens of this combination, and therefore its distance in rear of f_2 is obtained from the equation $XY = f^2$; where X is the distance of the aperature from the first focal plane of the second lens; Y the distance of "*e*" in rear of the second focal plane of the second lens; and *f* the focal length of the second lens.

The elementary astronomical or non-erecting telescope described above, consisting simply of an objective lens and a magnifying eye piece, is not suitable for naval purposes for the reasons that not only is the image inverted and reversed, but also that the movement of an object observed through such a telescope is reversed, so that an object moving to the right would appear to move to the left.

While gun pointers might possibly be trained to use such a telescope, it could only be achieved by long and arduous training, as it would be opposed by every natural tendency. Accordingly, we can immediately dismiss the thought of using this type of telescope.

It then becomes necessary to add an erecting system to the astronomical telescope with the disadvantage that each added lens uses up about 9° of the light which strikes it.

ELEMENTARY TERRESTRIAL TELESCOPE.

The elementary terrestrial telescope is obtained by adding an erecting lens to the simple astronomical telescope. The resulting lens system is shown in the accompanying Fig. 13,

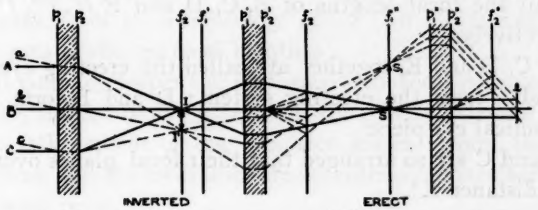


Fig. 13.

where three lenses are shown by the principal planes, $p_1 p_2$; $p_1' p_2'$; $p_1'' p_2''$. If A, B, C and a, b, c, are two parallel pencils radiating from the center and from the edge of a distant object, a real and inverted image will be formed as shown at II′ in the second focal plane of the objective lens. The only condition for the erecting system is that its first focal plane must be in rear of this inverted image. This erecting system or lens forms a real erect image at SS′. If this image is at the first focal plane of the eye piece, we have an elementary terrestrial telescope where the eye sees an enlarged image in its proper position. All that is necessary to convert this telescope into a gun-sighting telescope is to place cross wires either in the second focal plane of the objective lens, where the inverted image is formed, or in the first focal plane of the eye piece lens, where the erect image is formed.

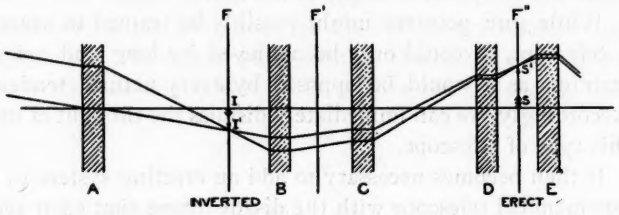


FIG. 14.

Fig. 14 shows the old Mark VII telescope. It consists of five lenses shown by their principal planes in the figures, lettered A, B, C, D and E.

A is the objective with focal length F.

Call the focal lengths of B, C, D and E f', f'', f''', f'''', respectively.

B, C, D and E, together are called the erecting eye piece; B and C form the erecting system; D and E form the astronomical eye piece.

B and C are so arranged that their focal planes overlap by by a distance K′.

D and E are similarly arranged, their focal planes over-

lapping by a distance K″, and the first equivalent focal planes (F′, F″) of both pair of lenses will consequently lie between them (see Fig. 11). Reference to Fig. 13 will show that B and C will perform the function of the erecting lens, as their first equivalent focal plane F′ is in rear of the image II′ formed by the objective.

B and C form an erect image at SS′. If this image is at the first equivalent focal plane of D and E, the telescope condition is fulfilled.

Assume

f as the equivalent focal strength of the system B, C, D and E,

f_1 as the equivalent focal length of B and C,

f_2 as the equivalent focal length of D and E, and

x the distance between the second equivalent focal plane of BC and the first equivalent focal plane of DE.

Then

$$f=\frac{f_1 f_2}{x};\ f_1=\frac{f'f''}{K'};\ \text{and}\ f_2=\frac{f'''f''''}{K''};$$

$$\therefore\ f=\frac{f'f''f'''f''''}{x\,K'K''};\ \text{but}\ M=\frac{F}{f};$$

$$\therefore\ M=\frac{FxK'K''}{f'f''f'''f''''}.$$

This equation for M shows the various ways of changing the magnification of the telescope. The magnification is increased by increasing F (using an objective of a longer focal length); or by increasing x, K′ or K″ (changing the position of the lenses); or by decreasing f', f'', f''' or f'''' (using eye-piece lenses of shorter focal lengths).

In all later telescopes the first equivalent focal plane of the eye piece, instead of lying between the eye-piece lenses as in Fig. 14, falls outside of the eye-piece lenses toward the objective lens, and the cross lines are accordingly moved forward to the same point.

FINAL VIRTUAL IMAGE.

(FIG. 15.)

As previously stated, the erect image formed in rear of the erecting system is real and can be seen on a screen placed at the proper point. This image is, however, very small and it is necessary to magnify it by means of the eye piece. The image actually seen by the observer is a virtual image of the erect real image and the cross lines. This virtual image is projected out in front of the eye piece at a distance depending upon certain conditions.

An examination of Fig. 13 in connection with the formula $XY = f^2$ will show that there are three cases possible in image formation by a positive eye piece, such as is used in erecting telescopes:

I. If the real erect image is in front of the first focal plane of the piece the emergent pencils are convergent, X is positive, Y is positive, and a real inverted image will be formed in rear of the second focal plane.

II. If the real erect image is in the first focal plane of the eye piece the emergent pencils are parallel, X is zero, Y is infinite, and a virtual erect image will be formed by the eye piece at infinity.

III. If the real erect image is in rear of the first focal plane of the eye piece the emergent pencils are divergent, X is negative, Y is negative, and a virtual erect image will be formed in front of the eye piece at the point where the rays intersect.

All erecting telescopes are found in case II or case III. Where conditions are as given in case III, the distance of the real erect image in rear of the first focal plane is so small that the virtual image will be formed at a great distance and, to the observer, will occupy practically the same position as the object itself; so that all the figures and formulae previously given will apply perfectly.

When an object is viewed through a telescope the final virtual image appears much nearer than the object; but, as

stated above, this is not the case, the final virtual image and the object occupying practically the same point. The apparent nearness of the image is an optical delusion, caused by the increase in detail due to the magnification.

THE FIELD LENS.

An examination of any modern telescope will usually show that the eye piece (Fig. 15) consists of three lenses, the two eye-piece doublets A and B, and the field lens, or eye-piece collective lens C.

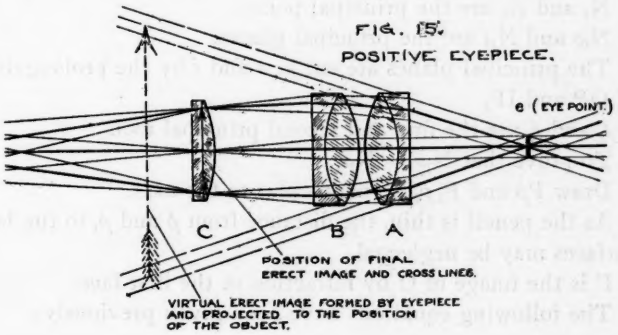


FIG. 15.
POSITIVE EYEPIECE.
e (EYE POINT)
C
B
A
POSITION OF FINAL ERECT IMAGE AND CROSS LINES.
VIRTUAL ERECT IMAGE FORMED BY EYEPIECE AND PROJECTED TO THE POSITION OF THE OBJECT.

The cross lines are etched by hydrofluoric acid on one of the inner faces of the compound lens C, then either silver and copper plated or filled in with a mixture of zinc sulphate and water glass, the two parts of the lens being cemented together with Damar balsam. In this way the cross lines are protected from injury and dirt.

It is apparent from Fig. 15 that when the pencils of light pass through the field lens C, a convergence is caused and the eye, situated in rear of A at the eye point *e*, will receive more of these pencils of light than would be the case if the field lens were not used. With the same diameter of eye piece, the use of the field lens enlarges the field of the telescope, hence its name.

PROOF OF THE PRINCIPAL PLANE THEOREM.

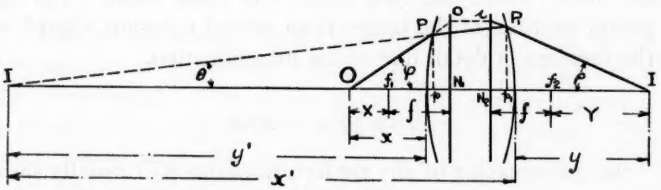


FIG. 16.

OP is a ray of a thin pencil of light from O, and P_1I is its path after emergence, forming the image I of the object O.

N_1 and N_2 are the principal points.

N_1o and N_2i are the principal planes.

The principal planes are cut at o and i by the prolongation of OP and IP_1.

f_1 and f_2 are the first and second principal foci.

To prove that $N_1o = N_2i$,

Draw $P\phi$ and $P_1\phi_1$ perpendicular to the axis.

As the pencil is thin, the distance from ϕ and ϕ_1 to the lens surfaces may be neglected.

I′ is the image of O by refraction at the first face.

The following equations have been given previously:

$$XY = f^2;\ M = \frac{f}{X};\ M = \frac{yy'}{xx'}.$$

From Fig. 16,

$$\tan\varphi = \frac{P\phi}{x};\ \tan\theta = \frac{P\phi}{y'} = \frac{P_1\phi_1}{x'};\ \tan\rho = \frac{P_1\phi_1}{y}.$$

Equating value of $P\phi$ and $P_1\phi_1$,

$$x\tan\varphi = y'\tan\theta, \text{ and } x'\tan\theta = y\tan\rho;$$

$$\tan\theta = \frac{x\tan\varphi}{y'} = \frac{y\tan\rho}{x'};$$

$$\frac{x\tan\varphi}{y\tan\rho} = \frac{y'}{x'};$$

$$\frac{\tan\varphi}{\tan\rho} = \frac{yy'}{xx'} = M;$$

Also,

$$\tan\varphi = \frac{N_1 o}{X+f}, \text{ and } \tan\rho = \frac{N_2 i}{Y+f};$$

$$\frac{\tan\varphi}{\tan\rho} = \frac{N_1 o(Y+f)}{N_2 i(X+f)} = \frac{N_1 o\left(\frac{f^2}{X}+f\right)}{N_2 i\,(X+f)} = \frac{N_1 o(X+f)f}{N_2 i(X+f)X} = \frac{M(N_1 o)}{N_2 i}$$

But

$$\frac{\tan\varphi}{\tan\rho} = M,$$

$$\therefore M = \frac{M\,(N_1 o)}{N_2 i}.$$

Or

$$N_1 o = N_2 i.$$

EFFICIENT RADIO STATIONS.

By Richard Pfund.

With any given amount of power, it is not entirely the system, or the apparatus, that determines the transmitting efficiency of a radio station. It is its location and how the apparatus is installed that determines this, and particularly on land, and although the author's explanation may not agree with other theories, much experience and observation has nevertheless convinced him that the efficiency of such apparatus is most decidedly increased if its installation is carried out with a view to meeting the requirements indicated.

Briefly, two of the most important and most essential requirements for best efficiency, are, on one hand, as perfect a connection with the earth as a whole, or as large a portion of it as it is possible to obtain, and on the other hand, a suitable antenna, or elevated capacity area. As it is not always possible or practicable on land to obtain a sufficiently perfect connection with the earth by direct contact, a so-called counterpoise, or capacity earth, may have to be employed in order to, as it were, obtain a more effective grip upon as large a conducting area underneath as possible. The larger this area obtained, either by direct contact or inductively by means of a counterpoise, and the better and more uniform its conductivity, and the better in turn its contact with other and still larger and better conducting areas, the greater will be the efficiency of the station, and particularly when transmitting. As sea water is a very good conductor indeed, and as it forms the most extensive and most continuous conducting areas on the earth's surface, the most desirable location for a land station, under ordinary conditions, is at the seashore. Simply locating it near the sea, however, is not enough, but for best results it

must be located on a site between which and the sea a connection of low resistance already exists. With this end in view the station should be located at sea level, or below it, and, if possible, on marshy soil and as close to the sea as practicable. A quarter of a mile inland, or even on top of a low hill close to the sea, may make all the difference in the world on account of the character and extent of the intervening soil. In this connection the author vividly recalls the efforts that were made, and his practically complete failure, about eight years ago, to establish communication, with about 2 kw. at each end, between the old, and since abandoned, U. S. Navy Stations at Highlands, N. J., and Montauk Point, N. Y., both of which stations, although directly on the coast, were on top of dry hills. At about the same time, and with about the same power and equally efficient apparatus, the old Deforest Manhattan Beach Station, located in a salt marsh near the ocean at Coney Island, was breaking all previous records for range, and its high efficiency, as compared with other similar stations of that time, was no doubt due solely to its low resistance ground connection with the Atlantic Ocean, which the stations at Highlands and Montauk Point were unable to obtain on account of their location. The remarkable ranges obtained a little later, but still with comparatively low-power apparatus, at the U. S. Navy Stations at Fire Island, N. Y., Newport, R. I., Norfolk, Va., and Key West, Fla., on the Atlantic Coast, and at Mare Island, Cal., and other Pacific and Alaskan Coast Stations, were also no doubt due, not entirely to more efficient apparatus, but primarily to their having a more or less perfect connection with large bodies of sea water, *i. e.*, large continuous areas of high conductivity, and nothing else. The fact that it has at times been found possible to establish communication between stations on the Atlantic and the Pacific, afloat and ashore, is also no doubt due to the same cause, and if, for instance, the stations at Newport and Mare Island, which have at times been able to get in touch with each other with low-power apparatus, could each be moved say five hundred miles inland and there provided with the best

possible ground connection obtainable, they would undoubtedly find it very hard, if not absolutely impossible, although a thousand miles nearer to each other, to establish communication, or get a single signal to each other with the same power as before, and simply on account of their grounds being of very much smaller area and very much inferior in conductivity to those they have on the coast, resulting in a very much higher ground resistance between them. The further fact that stations on the Pacific and the Alaskan Coast and on the Pacific Ocean have been able to far outstrip stations of equal power and equipped with similar apparatus on the Atlantic Coast and Atlantic Ocean, and also the fact that the ranges obtained in the southern hemisphere exceed those obtained in the northern with equal power and similar apparatus, is also no doubt due to the same cause. A first-class low-resistance ground connection is therefore of prime importance in radio work, and this does not mean simply a first-class local ground of comparative small area, but, in the author's opinion, if two stations on the earth's surface are to communicate with each other most efficiently, there must be a low-resistance ground connection between them, and not only at each end with no connection whatever, or one of high resistance, in between. Otherwise the results are likely to be similar to those obtained when it was attempted to ground a telegraph wire in a bucket of earth in a balloon. By making connection with large areas of high conductivity at each end the chances of getting through with a given amount of power are very much improved, because, although there may be a large body of comparatively poorly-conducting material between, as, for instance, the North American continent between Newport and Mare Island, the actual ground resistance between these two points may be quite small, because this large body of poorly-conducting material is sandwiched in between, and is in intimate contact on both sides with two very large bodies of high conductivity—the Atlantic and Pacific Ocean—and then in addition, straight across the surface of the continent is not the only conducting path between them.

So much for the ground, or, as the author prefers to consider it, the ground return, and the next important matter to consider is the antenna, or elevated capacity area. For best efficiency in transmitting, an antenna should not only be as far away from the earth as possible, but it should also, for a given transmitter capacity, have the largest possible electrostatic capacity, with the shortest possible natural period and smallest possible resistance. This not only means that in order to most efficiently absorb and radiate the amount of energy supplied to it by a given transmitter, the antenna best suited for that particular transmitter must have a certain definite electrostatic capacity, but it also means that there is also, with the present type of stations, a certain definite best height above the ground for this antenna, because the higher an antenna the longer will be the leads to it and the greater will be the inductance and the resistance and the longer the period of the antenna as a whole, and this increased period due more to inductance than capacity. It is therefore obvious that the most efficient height of an antenna for a low-power set is very much lower than that of one for a high-power set and that we cannot, with the present type of stations, go on raising the height of the antenna, with a given size set, without materially impairing the efficiency. It is, of course, possible to reduce the inductance and the resistance of the antenna leads by increasing their number and also by properly spacing them with that end in view, but such an arrangement adds very little to the efficiency and, if carried too far, will actually decrease it, because the greater the number of leads and the more their spacing approaches, or exceeds, that of the antenna proper, and the nearer these spaced leads are brought to the ground, the more such an arrangement becomes practically equivalent to bringing the entire antenna nearer the ground. This, although it may reduce the inductance and the resistance and increase the electrostatic capacity, at the same time also reduces the efficiency of the antenna as a radiator. The reason for this may be clearer if we assume that the antenna and the ground underneath represent the two surfaces of a condenser—which

of course, they really are—connected to the terminals of the transmitter. The closer these two surfaces are to each other the shorter will be the connection between them and the greater will be the capacity, but at the same time the greater will also be the tendency of the oscillating charges to confine themselves in this condenser circuit, made up of the transmitter and the antenna and the ground underneath and the air dielectric between, and the less the tendency of the antenna end of this condenser circuit to radiate its charges into space, or, as the author prefers to consider it, the less will be the ability of the antenna end of this condenser circuit to act most effectively upon the upper conducting strata of the atmosphere, which, in his opinion, play a very important part indeed in the transmission of the energy between distant stations in which one side of the apparatus is connected to ground. The author knows of no formula for obtaining the best height of an antenna for a given amount of power with the present type of stations and believes that it can only be obtained experimentally. He feels certain, however, and not entirely on theoretical grounds, but also from actual experience, that with the following arrangement both the height of the antenna and the efficiency for all powers can be very materially increased. Instead of locating the transmitter on or close to the ground, and connecting it with the antenna by means of long leads, the transmitter is located at the top, or near the top, of, for instance, a substantial metallic tower of ample cross-section and surface, depending upon the size of set to be employed, and with the different sections carefully bonded, and with perhaps several additional conductors of maximum surface and low resistance in parallel with the tower structure, so as to reduce both the inductance and the resistance to a minimum. The antenna, if only one tower is used, would be of the umbrella type and supported in the usual way and carefully insulated from the tower. The latter would be carefully grounded, either direct, if conditions make this possible, or inductively by means of a counterpoise attached to it. In the latter case, of course the tower would

also have to be carefully insulated from the ground. The antenna would be directly connected, when sending, to one side of the transmitter at the top of the tower with the shortest possible lead, and the tower itself would be directly connected to the other side of the transmitter with a similar lead. With a so-called flat-top antenna—no doubt the most efficient—and requiring two or more supports, at least one of these supports would be in the form of a substantial metallic tower of the same general type as that proposed for the umbrella antenna. This tower would be located at that point at which it is desired to make connection with the antenna, and the transmitter would be located at the top, or near the top, and connected to the antenna and the tower in the same manner as with the umbrella antenna, and the tower would also be grounded, direct, or inductively, as before. It would not be necessary to also locate the receiver at the top of the tower with the transmitter, but the receiver could be located at or near the bottom of the tower, with suitable control apparatus for connecting and operating the transmitter and for disconnecting it and cutting in the receiver in its place when it is desired to receive.

It is, of course, obvious that in case a metallic tower is not desired, one of brick, stone, or other material, could also be employed, provided a sufficient number of leads for connecting the transmitter at the top with the ground, and of such shape, etc., as would reduce their inductance and resistance to a minimum, were also installed. The inductance and resistance of the tower structure, if of metal, together with the leads in parallel with it, or of such leads alone if a tower of non-conducting material is employed, cannot, of course, be indefinitely reduced, but this conducting path to ground will always add something to the period and the losses of the antenna circuit. On the other hand, however, such an arrangement of the transmitter will very materially increase the efficiency of the antenna as a radiator, or, as the author prefers to consider it, its ability to most effectively and most efficiently act upon the upper conducting strata of the

atmosphere, because by putting the transmitter in close proximity to the antenna itself, instead of on or near the ground, and then extending the antenna down to it, the antenna, together with the connection between it and the transmitter, is kept at the maximum distance from the surface of the ground. By this arrangement the losses due to a too-close approach between the antenna and the ground, *i.e.*, the two sides of the capacity in which the oscillations are produced by the transmitter, are limited to those between the tower end of the antenna and the top of the tower, or the leads to ground from that point, and are small on account of the very much reduced area of these grounded surfaces close to the antenna and the comparatively low potential between these adjacent portions of the ground leads and the antenna.

SUBMARINES—IMPROVEMENTS.

By Lieutenant (J. G.) C. N. Hinkamp, U. S. N., Member.

In a general review of the improvements in the submarines during the last fifteen years we find many things that are of great military importance, principal among which is the ability of the submarines to cruise long distances, and to make these cruises with such regularity that it no longer excites comment. Other items of importance are improvements in signaling and the ability to navigate with comparative ease under all conditions of weather. Habitability has improved, cruising radii have increased, submerged running has developed to an exact science, and in general it is evident that there has been constant advance in submarine effectiveness. This will continue as experience dictates what is and what is not necessary to the development of the boats for the service that they are to perform, namely, the discharging of a torpedo against an enemy.

ENGINES.

Submarines opened the way for large engines of the internal-combustion type, but the inherent features of submarine design demand absolutely reliable engines of light weight and high speed—a difficult combination to obtain. As the size of the boats increased the engine horsepower and size increased, and the requirements became more stringent. Designers had difficulty in proportioning the weight necessary for engine reliability and that necessary for the proper trim of the boat. However, the gasoline engine was brought to a high state of efficiency, and the boats that are now fitted with gasoline engines are able to operate as effectively as some of the more modern boats. Before any departure in design is accom-

plished a great deal of preliminary experimenting must be done, in order to determine the weak points of the new design and avoid them in construction. The departures that have been taken in submarine-boat engines are as follows:

1st. Gasoline engines, heavy type, "A" class.

2d. Gasoline engines, light type, "B," "C" and "D," "G–1," "G–2" and "G–4."

3d. Diesel engines, medium weight, four-cycle, "E" and "F."

4th. Diesel engines, light weight, two-cycle, "H," "K," "L," "M" and "G–3."

5th. Diesel engines, medium weight, two-cycle, double-acting, for seagoing submarines.

6th. Diesel engines, heavy weight, four-cycle and two-cycle, for coast-defense submarines.

Each step in the past was a distinct departure. By constant operation and study the defects in engines have been found and are being eliminated, so that in future boats we will be able to decide on a design of engine and feel fairly confident of successful results.

The auxiliaries of submarine engines have been a constant source of trouble, and on them dependence is placed for the solution of the heat problem. Another difficulty lies in the quality of the metal used in the various parts of the engine. In internal-combustion engines the initial pressure is very much greater than in steam engines and the mean effective pressure is but slightly greater. Metal suitable for use in internal-combustion engines is still in the process of development, and it is hoped that the day is not far off when the problem will be solved.

In comparing the submarine engines of our Navy with those of foreign navies, the fact must not be lost sight of that extraordinary cruising feats are the order of the day with a long coast line, while in the foreign navies operations from a base and short cruises are the usual order. When one hears of a long cruise made by foreign submarines the impression is

gained that our vessels cannot duplicate the performance. But if the situation is studied one finds that our vessels cruise more and farther as divisions than do most individual foreign boats, and with little or no publicity. This means that great advance has been made, but decidedly does not mean that excellence has been attained. There must be constant and hearty understanding and coöperation between designer and operator, the former being guided by the advice and experience of the latter, to the end that, within the limiting restrictions of policies and appropriations, each new craft will be an improvement on the last, and each step a step in advance.

MOTORS AND BATTERIES.

Advances in electrical engineering have been responsible for many improvements in submarines, especially in the motors, the storage batteries, and the controlling devices for these parts. The motors are built more ruggedly, are of the interpole type, and, generally speaking, can take care of all the current that the battery can supply.

The early control was simple, plain knife switches being used. The first improvement was the enclosing of these switches to minimize the danger from sparks that might ignite stray gasoline vapors. The next step was the contactor-type of control for the main motors. This permits of many variations in the location of the control, but has the disadvantage of being somewhat complex. However, for the large currents now handled it is necessary to have this type, and except for its complicated construction it is very much liked.

Batteries are of the lead-plate type. Great improvements have been made in this type of battery in the last few years, but the inherent defects of the type will never be overcome. The greatest disadvantage of the lead-plate battery is danger from chlorine gas. There is no such danger in the Edison battery, which as yet has not been used in submarines because of its initial cost. The rugged construction and the absence of

dangerous elements make it appear, however, that the Edison battery, in spite of its cost, is the cheapest in the long run.

NAVIGATING.

One is not impressed with the hardships of the submarine service by the sight of a present-day submarine with its large bridge and adequate protection from the weather. But a view of an older boat with a very low bridge and little or no protection against the weather, would impress one with the desirability of staying ashore on a cold night. The boats, when cleared for action, of course have no bridge on them. When cruising about on the surface, however, there is no reason why a few of the comforts which are possible on a large ship cannot be had. At best, the devices installed are but makeshifts for the real thing on board a large vessel, but their installation eliminates a great many of the earlier difficulties met in navigating the boats.

The older boats had compasses which were mounted in helmets and which were very difficult to read. Today the boats have not only the gyroscopic compass and standard compass, but a steering compass and, in some vessels, a compass mounted in the top of the periscope for submerged work. All of these additional installations are being specified and required as a result of experience in submarines gained by various officers of the Navy during the last twelve or fifteen years.

The gradual adoption of improved devices for navigation has greatly reduced the possibility of accident to submarines when cruising, both submerged and on the surface. The greatest step in advance is in the engine and motor control. This originally consisted of bell pulls and similar devices, which could not be depended on. Today, however, very reliable electrically-controlled indicators are installed. These, in addition to being connected to a large bell, are visual, such that the operator is required to look at the apparatus and read the order that is to be executed.

GYROSCOPIC COMPASSES.

The variations and deviations of a magnetic compass are not fully realized until they have been met on board a submarine boat. The hull is of magnetic material, and the necessity of having as few protuberances as possible makes it necessary for the compass to be mounted near the hull. In addition, there are large electrical currents always present, and in use under many different conditions. To obviate some of the difficulties, the compass is mounted in a helmet of composition. In order to get the reading of the compass card into the vessel so that the helmsman can read it, a reflector is fitted. In some of the boats, a compass was mounted in the top of the periscope, but it was not generally relied on. All this is changed in the later boats. Gyroscopic compasses are installed in all these boats, and the captain no longer has to worry about his deviations. Direction has become a thing of electrical engineering plus gravity, rather than magnetic directive force. In a well-adjusted compass all that is necessary is the setting of the speed indicator and the course. It is possible for the helmsman to point the boat by fractions of a degree now, where heretofore it was a question of quarter points. This means a great deal to the man who has to fire a torpedo at an enemy, for it is possible to do so without showing the periscopes, after once having obtained the enemy's bearings.

PUMPS, BALLAST TANKS, DRAINAGE.

Hydraulic engineering has advanced in strides along with the other branches of engineering—steam, electric and gasoline —and the effect of this advance has shown itself in the installations in the submarines. Considering all the ways that water has to be handled in the boats, greatest progress has been made in the pumping systems. The air blowing has not been changed materially and the principles have been applied in much the same way in all the types of boats; but great strides have been made with the pumps. The older pumps were of

the plunger type of limited capacity and, sometimes, doubtful efficiency. The rotary pumps that were installed were weak, of primitive design, indifferent workmanship, and subject to all the ills of this type of pump. Now the ballast pumps are of the centrifugal pattern, can handle vast volumes of water in a short time against a head of water double that possible ten years ago. The rotary pumps are rugged in design and of a material that will withstand the ravages of hard service. They are built with an idea of being lasting and serviceable. Impellers are so designed and built that they have ample bearing surface, with adequate supports. In the early boats there was considerable trouble with the shafting. It was of composition and broke very easily. Steel shafting was substituted. By this substitution the shafting became the strongest part of the pump, and eliminated most of the troubles of this type. Pumps of turbine design for the ballast pumps are being experimented with in some of the boats, and great results are expected, as it is claimed that they can pump against a head of water equal to the depth of test submergence. In the early boats, and some of the later ones, the circulating-water pumps for the engines were direct-connected to the engine, through gearing or chain drives. Invariably these systems gave trouble. The latest practice is to have all auxiliary and main pumps independently driven and so arranged that every reasonable contingency is provided for.

SPEED IN SUBMERGING.

One of the vital military requirements of a submarine is rapid submergence from cruising conditions. For cruising in the small boats it was necessary to rig a complicated bridge for the helmsman and other members of the crew. This took some time to unrig at sea when preparing to submerge. It was generally necessary to stow all the parts inside the boat through the conning tower because the seas were generally too high to permit of opening the main hatch. As the vessels in-

creased in size the freeboard became greater, the danger of shipping a sea much less, and it was more feasible to unrig at sea. But it was not until a year or two ago that the collapsible bridge was designed and installed. With this style of bridge it is only necessary to stow the stanchions inside the conning-tower fairwater, to fold the bridge deck down to the sides of the fairwater and secure them in the pockets provided for that purpose. It is possible to get the later boats submerged in a few minutes, because the normal amount of buoyancy is so great as to permit of the admission of a quantity of ballast while the preliminary work of unrigging is going on. Formerly it was necessary to allow about twenty minutes for this operation. It can now be done in from four to six minutes. With the bridge unrigged it takes from two to two and one-half minutes to get under the surface, traveling at three-fourths speed. Design, construction and training are responsible for the enormous reductions in the time necessary to perform any evolution.

RADIO, SIGNALS, COMMUNICATION.

Following the pace set in other fields of engineering, progress has been made in the methods of signaling. The contractors and the signal engineers in civil life have coördinated in such a manner that many improvements in this branch have been incorporated in the installations of later vessels.

The means of signaling on the surface are practically the same in the submarines as on the larger vessels of the Navy; namely, radio, flag, shape and sound in the day time, and radio, sound and light at night. Submerged, the signaling has taken tremendous strides. In the older boats there was no method of outside communication except that improvised by the crews, and the method was primitive. It consisted in tapping a rivet with a hammer and picking up the sound by holding the forehead against a frame. The introduction of the submarine bell opened the way for the later and better methods of signaling, all dependent upon the principle of setting up vi-

brations or waves in the water that are detected by means of microphones and heard through the ordinary telephone receiver. Today the submarine is well equipped to send or receive signals under all conditions, and the methods in use are vastly superior to those used only five years ago. The chief difficulty at present encountered is due to the internal noises of the boat. By the introduction of sound-proof compartments this bad feature can be eliminated.

PERISCOPES.

Improvements in periscopes have been very marked. The early periscopes were frail and leaky, and generally became cloudy after a short time. The periscopes of the present time, a few of which are in service, are rigid, clear and watertight, and the periscope tube is enclosed in an outer tube which has but one joint exposed to the weather. In the early periscopes the image inverted when looking to the rear with the eye piece stationary. In the present periscopes the image remains erect, no matter what the position of the object glass, and the bearing of the object is indicated by a movable pointer on a fixed dial. In addition to the feature of erect image in any position of the eye piece, the periscopes have been so arranged that a magnifier can easily be put into operation. This is of inestimable value when picking up objects. As soon as the object is picked up and easily distinguishable, a reversion to the normal eye piece can easily be made. Ordinarily the periscopes are used without the magnifier, in order that objects will appear as they would to the unaided eye, and also that distances will not be distorted. The monocular and binocular periscopes of the present day have all the advantages of the modern telescope or binocular glass.

ARMAMENT.

All submarines depend for their defense on their ability to submerge. Their armor is the water over them. Their offensive weapon is the torpedo. The methods of handling

the torpedoes has been improved, but even today the methods are crude, consume a long period of time and require, above all, entirely favorable conditions for comparative rapidity. However, progress is being made along well-defined lines, and there is hope that some day in the near future a means of handling the torpedoes will be devised that will not require "all hands" for the job.

The torpedoes are pointed at the target by pointing the boat, and their course is the boat's course at the instant of firing. The angle of the torpedo's course from the direct line—boat to target—is set and determined by means of the torpedo director. These instruments solve the angles automatically, working from certain well-known data, and if the torpedo is well adjusted it will hit either a moving or stationary target. The old method consisted in solving the angles mathematically and then taking a chance.

TORPEDO TUBES.

Nowhere were improvements more necessary than in the torpedo-tube arrangement. The older types of boats required that all the tubes be flooded every time that a torpedo was fired out of one tube. The tubes were covered by a cap which seated on the tube ends thus keeping them watertight. Now, by a door device, controlled from the inside of the boat, any or all tubes may be opened at the same time. The apparent advantages of the later arrangement are many. It is not necessary to pull into the boat, in order to avoid wetting it, a torpedo in a tube adjacent to the torpedo about to be fired. In torpedo practice this advantage is very apparent, as it is possible to work on torpedoes without interruption and fire practice shots at the same time.

LOADING TORPEDOES.

It would appear that, inasmuch as the submarine is designed for the sole purpose of firing torpedoes, adequate means would

have been provided for loading these torpedoes in the vessels. In the "A" class of submarines it was necessary to break the torpedo up into its component parts to get it into the boat. In the " B" class the torpedo hatch was located aft and in such an inaccessible position as to make loading of torpedoes a practical impossibility. Besides the danger of a passing wave washing water into the boat, there was always the difficulty of trying to bend the torpedo around a stanchion inside the boat. To overcome this difficulty the torpedoes were generally sucked in the torpedo tubes and as soon as they were in the tubes the cap was closed, torpedo tube drained, and the torpedoes hauled into the boat. Thus, before any work was done on them, the torpedoes were wet and often damaged by handling. In the " C" class of submarines, greater attention in design was paid to the methods of loading of torpedoes. They could easily be loaded at an average of about 20 minutes each. In the " D," " E" and succeeding classes the torpedoes can be loaded complete, but the best arrangements devised are crude.

It was a long time before proper and adequate cranes or davits were fitted to submarines for the handling of torpedoes. In the early period of development, it was necessary to parbuckle the torpedoes on to skids and load the torpedo into the boat from the tender, using a boat davit for this purpose. It is hoped that better installations for the handling of torpedoes will be designed. At best, torpedo handling is difficult in a submarine, owing to the peculiarities of construction not met in any other class of vessels.

FIRING TORPEDOES.

Torpedoes are fired by the old lanyard method. In the first boats the commanding officer gave the order to fire to the man at the tube; he controlled the firing entirely. Later the air-control was used. This control was mounted near the periscope, and the commanding officer himself fired the torpedoes when the boat was on the target. It is hoped that, in the near

future, the torpedo firing will be electrically controlled, in order to reduce, in a measure, the firing interval.

CONNING TOWER.

The early submarines of the "A" class have a protuberance on the deck called a conning tower. Compared with the later models it is entirely unsatisfactory. In later designs, the conning tower not only contains the auxiliary navigating gear, but is so designed and constructed that it can be used for an escape hatch for the crew in case of accident. The latest practice requires all the periscopes to be in the hull proper, the reasons being that this construction makes for greater safety, greater ease in the handling of the boat submerged and, if navigating the boat on the surface in rough weather from the periscopes, permits of three lookouts, instead of two, one man being in the conning tower.

TANK CONSTRUCTION.

The vessels of the present day have tanks which can withstand a pressure equal to that which the exterior hull can stand. In the earlier classes of vessels some of the tanks were so built that they could withstand a hydrostatic pressure of but from 10 to 50 pounds, and, when submerged, were always kept closed. The construction today permits of leaving the tanks open to the sea pressure without danger. In the construction of double-hull boats of various designs it is not necessary for the outer hull to be as strong as the inner hull, as it cannot be deformed, owing to the fact that it is completely filled with water. But the inner hull, or the hull proper, must be built to withstand the hydrostatic pressure of the specified depth to which the vessel is tested. Thus the present-day construction tends towards greater safety in the boats because the operators may safely put a high pressure on their tanks. With the sea valves closed, tanks can be pumped at any depth that the hull can stand.

CRUISING CONDITIONS.

The one great feature is the present-day submarine, which makes it possible to undertake long cruises, is the subdivision of the boat into compartments. In the "A," "B" and "E" classes there are no compartments, and the noise of the engines, which can be heard all over the boat at all times, is very loud and practically prevents any one from sleeping. Also, the one-compartment construction permits waste gases from the engine to permeate the entire atmosphere of the vessel, causing the men to become sick when any leaks occur about the machinery. The "C" class, after acceptance by the Government, were subdivided by a light bulkhead. In succeeding classes, "D," "F," "G," "H" and "K," the compartment construction was required, and the cruising success of present-day vessels is due largely to this construction. In addition to the comforts which are possible with this construction it makes for a degree of safety in the submarine which otherwise would be entirely absent. Any explosion or fire can be localized in the compartment where it originated and the crews can live safely in the other compartments. In case of a rupture to the outer skin of the ship it is possible to confine the flooding waters to a small area. The latest boats are so built that the flooding of one compartment will not completely sink the vessel.

HEATING.

To any one who has made a cruise up and down the coast in the winter time in a vessel without any heat the question of adequate heating appeals very strongly. The submarines of the "A" and "B" classes were not regularly provided with heaters, and great were the hardships encountered when cruising in northern waters. It was not until winter cruising became the rule rather than the exception that the idea of heaters was agitated to any extent. Electric heaters were at first supplied, but these absorbed large quantities of current from the storage battery. This reduced the submerged radius or re-

quired constant running of the engines to maintain the battery in a proper state of charge. The latest boats are fitted with steam heaters. These should eliminate many of the hardships attendant on winter cruising in northern waters.

HABITABILITY.

Going to sea in the early submarines is as near as one wants to approach to a real dog's life. Bridges are small, berthing of the men is difficult, there is little heat and the facilities for cooking are far from good. In the later boats these relics of barbarism have vanished to a large extent, and in their places are more modern equipment. The bridges are better, have more navigational facilities, and can be closed in for cold or extremely wet weather. In fact, cruising is more of a pleasure than it used to be, consequently the efficiency of the submarines is greatly promoted, and cruising efficiency is next in importance to the actual attack which is so dependent upon it. When the members of the crew know that they can turn in after a watch in a comfortable place, and feel assured of well cooked food, the general atmosphere is better. Contentment in this service, which requires the best efforts of the men at most unexpected times, and under very trying circumstances, must be most carefully considered. The advent of fuel oil as fuel for the engines, instead of gasoline, added largely to the safety of the vessel by reducing the danger from fire and explosion.

COOKING.

The comfort of the crew was not considered fifteen years ago. From the viewpoint of the present day, it appears that every discomfort which it was possible to conceive of was quite in order. The modern submarine has every comfort commensurate with the size and service of the vessel. The principal item making for comfort is, of course, properly-prepared food. The early boats used an alcohol stove, contrary to all rules and regulations for the safety of vessels burning

gasoline, but the men preferred to take this chance rather than have cold food. For this they cannot be blamed.

As time passed, electric cooking apparatus was installed. This was always subject to the many troubles inherent in early electrical heating apparatus. However, the idea was a step in advance. Today there is installed a well-arranged oven, four or five independent plates for cooking meats and vegetables, and an urn for keeping coffee constantly hot and on tap when cruising. All of these things, though small in themselves, make for contentment in the crew.

An important consideration for a long cruise is the stowing of adequate fresh provisions and an ample supply of dry food. The early boats had no means whatever of stowing food. What was not carried in cans was not carried at all. Now the vessels are provided with an ice-box large enough to stow three or four, and sometimes five days' supply of fresh meat and vegetables. The crew receive a ration equal to that served on our largest vessels. Dry food is stowed in specially-built lockers. The electric cooking, of course, is somewhat slower than cooking on a range fired by coal, but one man is detailed for this duty, and it keeps him busy. He is able to devote all his efforts to proper cooking. The present installations provide for all emergencies and are considered very good.

WATER STOWAGE.

Owing to the longer cruises taken by the boats, and the necessity for living on board many days at a time, the question of fresh-water stowage became an important one. The usual practice was to carry all the water the fresh-water tanks would hold, fill up the water breakers, hope that nothing would happen to the water, and trust that no one accidentally took a bath. The water was generally apportioned in such a manner that the crew were able to get two washes a day and all they needed to drink. This was very satisfactory. But to insure a ready supply, not only for the crews of the boats, but also for the

storage batteries, a small distilling plant is now installed that is capable of caring for the most extravagant needs of a crew. This may appear to be a needless refinement, but until the tenders for submarines are brought up to the standard that the service requires, and their number and their size is adequate, all these apparently extravagant mechanisms have to be installed. It is economy to have adequate tenders. Then many comforts could be obtained without the necessity of carrying so many auxiliaries on board the submarine, and the consequent saving in weight could be used in the design of more rugged and reliable engines.

SUBMARINE TENDERS.

The tenders for the submarines are inadequate. All of the tenders, so-called, except one, are make-shifts and, generally speaking, are not suited for the purpose. It is practically the only branch of the submarine service that has not shown a material improvement during the development of the submarine. There is only one submarine tender in commission that was designed as such, and another is building. Several are needed.

CONCLUSION.

Development has been conservative, improvements have been many, efficiency has been promoted, reliability has been increased, but the field is still open to advances, and the efforts of all should be bent to the establishment and execution of a safe and sane policy that will mean steady growth and progress in ALL branches of the submarine service.

ADDITIONAL NOTES ON SUBMARINES.

By George W. Baird, Rear Admiral, U. S. N. [Retired], Member.

As early as 1814 Robert Fulton wrote a letter to the President, Mr. Madison, on the subject of Torpedo Warfare and Submarines which, after a whole century, reads like a prophesy.

Mr. Fulton, in the letter, recites his experiments on submarine explosions, his floating mines, anchored torpedoes, submarine boat, etc., which seem to have anticipated the wonderful development of the submarine of today.

He met, naturally, earnest and determined opposition from naval officers in this country, in France and in England, who were probably wedded to the glorious and romantic traditions of the Service, as well as feeling an abhorrence of the ungallant and unseamanlike method of destruction of life and property.

The United States Navy was then controlled by a Board of Commissioners, with Commodore Rodgers as president and Captain Chauncey an active member, but subordinate to the Secretary of the Navy.

Congress appropriated $5,000 to defray the expenses of the Fulton experiments. Fulton sought to prove that gunpowder could be burnt under water with explosive violence; that cables (anchor cables were then made of rope) could be cut under water, leaving the ship to drift, and that torpedoes could be fastened to ships' sides with harpoons, fired from small arms, the harpoon being attached to the torpedo by a line; that torpedoes, on poles, could be thrust under ships and fired.

His plans were fully explained to the Commodore, a com-

mittee of Congress, and all others interested. The art of seamanship at that time was at its very highest, and American seamen were not excelled by any in the world, so that when the commanding officer of the *Argus* received an order to prepare a defence against a sham battle of torpedo attack, and knowing well the full particulars of the torpedoes and the method of attack, he knew at once just what to do. It was simple and was quickly executed. He surrounded the ship with his spare spars, held at a distance which exceeded the length of Fulton's poles, and dropped a netting from the water's edge to the bottom of the river, which were sufficient to defeat the operations of Fulton while the *Argus* was at anchor. This was made easier by the fact that Fulton had in his employ but a few men, and they were not seamen.

He did, however, succeed in cutting a cable under water and sending a ship adrift, and he proved that it was easy to explode gunpowder under water. He said that superior seamanship and previous knowledge of his methods, more than defects in his inventions, had foiled him in the North River experiments, and insisted that his devices in the hands of skilful operators would have succeeded. In this the Hon. Cadwalader D. Colder agreed, but the Commodore reported that "all that has been proven relative to this description of torpedo amounts to nothing when compared with the object for which it was constructed."

Fulton took his inventions to England, as many other Americans have done since then, and, in England he proved by test that ships could be destroyed from a distance, when he blew up the brig *Dorothea,* in October, 1805, in the presence of Mr. Pitt and Lord Melville.

The torpedo used was of the floating kind, which was carried by the tide to the brig, and exploded on contact. He repeated this in the presence of Admiral Holloway, Captain Owen and Captain Kingston, and quoted Captain Kingston as follows: "Twenty minutes before the *Dorothea* was blown up Captain Kingston asserted that if a torpedo were placed under

his cabin while he were at dinner he would feel no concern for the consequences."

Earl St. Vincent was quoted as saying " Pitt was the greatest fool that ever existed to encourage a mode of warfare which those who commanded the seas did not want and which, if successful, would deprive them of it."

Fulton had, before going to England, recommended that a large number of torpedo boats be substituted for a number of frigates, and showed by his figures how much less it would cost the nation. This was, probably, very provoking to the men " who commanded the seas," but, at the same time, it was out of the question for aggressive warfare, though the plan would be a good one for harbor defense.

Fulton's anchored (contact) torpedoes had the essential features of the modern mines, but lacked the size, high explosive power and mechanical construction which the state of the arts has now made possible.

Fulton declared that ships would never be sailed into harbors where torpedoes were anchored.

His submarine boat, the *Nautilus,* which he produced later was, in its essential features, the same as that of McClintock, shown on page 846, Vol. XIV.

Fulton was, however, apprehended by Bushnell, who was not only the pioneer of submarine-boat designers but invented the first screw propeller ever used, and for that boat.

David Bushnell, a recent graduate of Harvard University, was a native of Saybrook (now Westbrook), Connecticut, and, in 1775, entered upon mechanical pursuits and inventions.

The writer has made exhaustive searches for drawings or any trace of drawings or sketches of Bushnell's boat (the *Turtle*) without success, but from a description of the boat the writer has produced Plate I.

History shows that a Sergeant in the Revolutionary Army, named Ezra Lee—afterwards an Ensign—went down in the *Turtle* for the purpose of attacking one of the ships of the enemy. He reported that at a depth of three fathoms there

was light enough in the vessel to read by. He had 700 pounds of ballast, of which 200 were detachable at will, to increase the buoyancy of the vessel. His depth was determined by a syphon gage. His propulsion was hand-power, as shown. The torpedo, of the clockwork variety, was detachable (as shown), and attached by a line to a screw which was intended to be driven into the bottom of the ship of the enemy, as shown. He could propel the boat at the rate of three miles an hour for a short time.

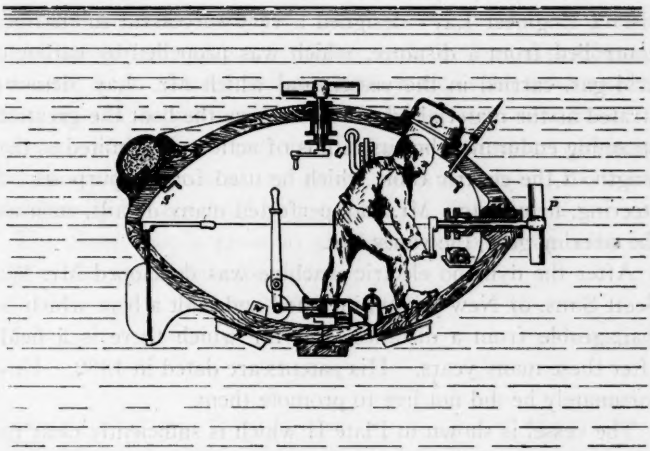


PLATE I.—BUSHNELL'S AMERICAN TURTLE, BUILT AND USED IN 1776.

He made but one attack. He reached the vessel, which was at anchor, only to find that he could not drive the gimlet-pointed screw through the copper sheathing of the ship. His torpedo became detached, floated down the river a short distance and exploded. This failure was simply for want of experience and for perfection of details.

In Vol. XIV, page 845, the writer has given a drawing and description of the famous submarine boat of McClintock which was used to destroy the *Housatonic*. In Vol. XXIV

the method of Col. Colt is also given for locating the position of a ship over a mine by a single observer on shore.

The periscope, now so successfully used in the submarine, and also the means of chemically purifying the air, are given, but the state of the art at that time had not reached mechanical propulsion under water.

The boat designed by Chief Engineer Wood and used so successfully by Lieutenant Cushing in the destruction of the *Albemarle* was essentially a surface boat, and has no place in the submarine class; but Mr. Wood's assistant (Second Assistant Engineer Lay) designed a very successful submarine, controlled from a distance, which was propelled by carbonic acid gas, carried in the vessel, and which Mr. Lay demonstrated as the material which would give the boat the greatest steaming endurance, but its radius of action was limited to the length of the electric cable which he used for the purposes of steering, firing, etc. Mr. Lay perfected many details, such as the steering gear, the vanes, etc.

After the dynamo electric machine was developed Mr. W. Scott Sims, of New Jersey, invented and built a boat which is manageable from a distance, and for which there is a field after these many years. His patents are dated in 1882. Unfortunately he did not live to promote them.

The vessel is shown in Plate II which is sufficiently clear to be understood by the readers of this journal.

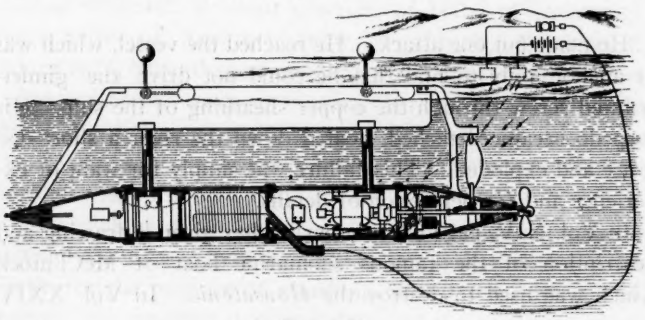


PLATE II.

The boat is propelled by an electric motor in the boat, the current being supplied by a machine on shore or on board a vessel, and its radius of action is limited to the length of the cable from the dynamo.

Mr. Sims found, as Fulton and McClintock had found, that it was difficult to keep his vessel on an even keel, no matter what her shape, when she was submerged and not in motion, and this was more difficult the sharper the model. Finally he made his vessel cylindrical, with the ends sharpened, and further attached a surface boat, as shown, with low freeboard, to keep the hull on even keel.

For sweeping a harbor of mines, with the least risk of life, the Sims boat, if used in pairs with a chain bridle between them, would be admirable. It would present a small target even when discovered, and if the surface boat, which is tied to the torpedo boat, as shown, were destroyed, the boat could easily be recovered by the cable.

The Sims boat is probably the least expensive to build of any of the automobile torpedoes.

NOTES.

THE FUTURE OF THE BATTLESHIP.

By Archibald Hurd.

On the very eve of the outbreak of war Admiral Sir Percy Scott stated that he could see "no use for a battleship and very little chance of employment for a fast cruiser" in future naval warfare. He announced that he had been driven to the conclusion that the submarine, with its menacing torpedo must be regarded as the supreme arbiter of naval supremacy. He looked forward to a complete change in the constitution of all navies: "Naval officers will no longer live on the sea, but either above it or under it, and the strain on their systems and nerves will be so great that a very lengthy period of service will not be advisable. It will be a navy of youth, for we shall require nothing but boldness and daring." He even went so far as to declare that the building of any more battleships in the present financial year would be "a misuse of money subscribed by the citizens for the defence of the Empire."

How far has the experience of the war sustained the contentions of this distinguished admiral, who has gained worldwide fame owing to his successful introduction of new methods for gaining the maximum fighting power from above-water vessels carrying the gun?

Every new instrument of warfare has a tendency to exert, for a time, an undue influence on public opinion, and sometimes also on naval opinion. When the automobile torpedo first made its appearance the First Lord of the Admiralty of that period announced that there was no intention of laying down any more battleships, as it was believed that the new weapon would drive the battleship, with its powerful guns, off the seas. At that time the submarine had not made its appearance, but considerable sensation had been created by the success of the French naval authorities in the construction of swift small surface vessels carrying the torpedo. In the course of various trials, which lacked reality, these little craft seemed to many observers to carry almost everything before them. The sensation and its influence upon constructional policy lasted for a few months, and then the inevitable awakening came and the building of battleships was once more resumed and continued with uninterrupted and increased vigor during later years.

The appearance of the submarine as a sea-going craft with great radius of action revived the belief in the superiority of the torpedo over the gun. Sir Percy Scott was not the first naval officer by any means to prophesy that the submarine would in future exercise primacy on the seas. As long ago as the spring of 1910, at a meeting of the Institution of Naval Architects, Rear Admiral Reginald Bacon read a paper on "The Battleship of the Future." He pointed out that "the problem of building a ship which cannot be sunk by the explosion of a torpedo is one that has exercised the skill of naval architects, and the design of a ship which shall not be incapacitated by such an attack has hitherto baffled all solution." Admiral Bacon did not go so far as to say that the battleship would become obsolete, but he urged certain conclusions of a somewhat revolutionary character as to changes in the type which met with considerable opposition from more conservative naval officers. Concluding his paper he said:

"All the considerations of offence and defence point to increase in size of battleships as modern gun construction advances. But since the modern battleship no longer holds the supreme position which, in the old days, made the battleship the sole ultimate arbiter of sea power, it is improbable that, as the torpedo improves, battleships, unable to defend themselves against any form of torpedo attack will be built merely to fight battleships.

"One function of the large cruiser will, therefore, be assumed by the battleship, high speed will become more and more necessary, and armor protection will be less accentuated than at present. The link between the ocean-going destroyer and the battleship will become closer, and one may reasonably expect that the huge monsters of the future will always be accompanied by torpedo craft of high sea-going speed as defensive and offensive satellites.

"The battleship, as now known, will probably develop from a single ship into a battle unit, consisting of a large armored cruiser with attendant torpedo craft. Line of battle, as we now know it, will be radically modified, and the fleet action of the future will, in course of time, develop into an aggregation of duels between opposing battle units. The tactics of such units open up a vista of most exhilarating speculation, and will afford to the naval officer of the future a scope for his tactical skill never dreamed of by us or our predecessors.

"The whole future is pregnant with radical obliteration of our present notions as regards tactics; but we may confidently prophesy that size of ships and power of gun will increase and increase until war, the great arbitrator among theories, will confirm or reconstitute our opinions regarding naval armaments."

Since Admiral Bacon wrote these words war has occurred. Popular imagination has been excited by the success of the submarine. No sooner had hostilities opened than a German submarine scored its first success by sinking the *Pathfinder*. Later on the three cruisers, *Aboukir, Cressy* and *Hogue* were destroyed by the same agency. Submarine attack was responsible for the sinking of the *Hermes* and the *Niger,* and in the Baltic the Russian cruiser *Pallada* fell a victim to the same type of ship. Moreover, it soon became common knowledge that German submarines had passed through the Straits of Dover into the English Channel and had cruised in far Scottish waters. Those who are unfamiliar with the development of the submarine were not a little surprised to learn that these vessels could proceed so far from their base, and it was thought that they must have some secret sources for the supply of fuel to enable them to travel 500 or 600 miles from the German coast. Those who had watched the progress of submarine construction were, however, in no way surprised by the activity of the enemy's under-water craft. They were aware that the submarine had been evolved into a vessel of considerable size, no mean habitability, and great radius of action. It was anticipated that during the course of the present war the submarine would exercise no little influence on the course of events.

The Board of Admiralty by the very success with which it mobilized the whole strength of the Royal Navy on the day preceding the declaration of war, saved the British Empire from many terrors and heavy losses, but at the same time conferred on the enemy the advantages of conditions favorable to the use of the submarine under the most favorable circumstances. By mobilizing the British Fleet before the German navy was ready, the Admiralty achieved two ends. In the first place they prevented war cruisers and converted merchant cruisers from escaping on to the trade routes, and Germany had in consequence to rely exclusively upon such vessels as happened to be at large when hostilities broke out. In the second place they robbed the German navy of the immense advantage of offensive initiative. It had been the deliberate policy of the Germans to

strike before our squadrons had been concentrated and had reached their war stations. In this the Germans were defeated. The British Fleet from the very opening of war converted the North Sea into practically a *mare clausam,* and sealed, to all intents and purposes, the two exits. The main naval operations of Germany were thus confined from the very opening of war to one of the most restricted oceans. The North Sea, considered in isolation, is a very large area of water, being of about 220,000 square miles in extent—in other words, it is two and a-half times the size of Great Britain. Considered, however, in relation to the other great seas of the world it is extremely small, since five-sevenths of the globe is covered by water. What British strategy effected was to confine the High Sea Fleet of Germany and its flotillas of destroyers and submarines to this area. The ships could escape only by accepting the challenge continually offered by the Grand Fleet under Admiral Sir John Jellicoe. This, on the one hand. On the other, these conditions offered to German submarines almost ideal opportunities for proving their usefulness, since the offensive-defensive policy of our Navy kept our forces concentrated within range of the enemy's submarines.

German submarine tactics have nevertheless so far proved a failure. No one would dare prophesy what the future course of the war may reveal, but a careful examination of all the evidence at present available shows that Germany's submarines have achieved no success which can influence the ultimate issue of the war, and that nothing has yet occurred to confirm the impression that under-water craft have rendered battleships and cruisers useless. Consider the leading events of the war. Did German submarines prevent a dozen large British ships invading the Bight of Heligoland and practically annihilating a considerable force of German cruisers and destroyers? Have German submarines prevented the ships of the Grand Fleet from sweeping the North Sea on more than one occasion, practically from end to end without loss? Have German submarines interfered with the most wonderful operation of which history contains any record, namely, the transport of British troops across the Channel, and the convoy to the Continent or to this country of tens of thousands of soldiers from the Dominions or from India, or have they succeeded in interfering with the general post which has been carried out in order to rearrange our garrisons overseas to fit in with the new strategical situation which came into view when war occurred? Have German submarines been able to save the German men-of-war, which were on duty in the outer seas, from being rounded up and destroyed? Have German submarines kept the seas for Germany's mercantile marine?

In each and every one of these respects the submarines of the enemy have failed. The successes which have been achieved have been achieved under favorable circumstances. The enemy's under-water craft have sunk a limited number of British ships, but they were slow ships, or at least were steaming slowly at the time of attack, and one of them was anchored when attacked. No submarine of any navy has yet been able successfully to attack battleship, battle cruiser, or armored cruiser when steaming even at her economical speed. The submarine, in fact, has been revealed as a type of ship which can be employed with deadly effect against large ships of deep draught when they are either at anchor or steaming slowly.

It is significant of the impression which the war has produced on expert minds in other countries, that on the other side of the Atlantic the victories which have been gained by German submarines have not yet affected constructional policy. In its last session Congress authorized the building of three of the largest battleships ever designed. These ships had not been begun at the time when war occurred. Considerable curiosity was felt as to what action the Navy Department of the United States would take in view of the early successes of the under-water craft in the

North Sea. It was assumed that the American naval experts would not ignore the progress of events in Europe. It soon became known that they were indeed watching matters with the closest possible attention. Week succeeded week and no action was taken, but at length it was announced that it had been determined to proceed with the construction of these three ships. This announcement was followed by the publication of a memorandum which put on definite record the conclusions which the Department had reached as to the limited influence of the submarine.

In accordance with these views not only have the keels been laid down of three battleships, which are of 32,000 tons displacement, but Congress has been recommended in its present session to authorize the construction of two more of these large units. It is thus apparent that the naval authorities of the country which, when the war opened, was running a neck-to-neck race with Germany for the position of second greatest naval power, have no intention of abandoning the construction of large-gun ships. They still believe that the battleship holds its traditional position as the ultimate arbiter of sea power and it is intended to pursue an active policy of construction.

The most remarkable fact revealed in this connection is that the Americans still persist in refusing to build battle cruisers, and are content with vessels with a speed of only 21 knots. It was reported early in last year that the General Naval Board favored an advance of speed to 25 knots, and the limitation of the number of guns to eight of an increased caliber, going from 14 to 16 inches. A vessel of this type would have been an improvement on the *Queen Elizabeth* class, and would have involved a very great increase in individual cost. It is understood that the Navy Department viewed this departure with no favor. Consequently the American Navy is being provided with armored ships deficient in speed in comparison with many vessels which have been constructed for the navies of European Powers, and at the same time no effort is being made to build any swift ships ranking in size between the battleship and the destroyer. No cruiser of any kind has been laid down for the American Navy since the three vessels of the *Birmingham* class were launched in 1907. The result of this policy is becoming apparent. Next spring the United States will possess only 13 cruisers of less than fifteen years of age and displacing 6,000 tons, and will have only nine small cruisers. Most of these ships are becoming obsolete and are relatively slow, and yet the new shipbuilding program shows that there is no intention of making good the growing deficiency in cruising ships, and expert authority has refused to increase the speed of American battleships. Of course the strategical conditions in American waters are radically different from those which affect the policy of European Powers, but nevertheless this continual neglect of cruiser types and contempt for the value of speed in large armored units must cause some surprise.

It may be assumed on all the evidence which is available that the battleship will continue to exercise primacy on the seas and that, in spite of the policy which the Americans are pursuing, cruisers in considerable numbers will continue to be built by the leading naval Powers. But the battleship of the future will undoubtedly differ very considerably from the battleship of the present. Of all the revelations which the war has made none has been so remarkable and awe inspiring as the ease with which a well-aimed torpedo can destroy the largest of vessels. One of the cruisers of the *Cressy* type was sent to the bottom by a single torpedo. She was designed before radical changes were made in hull construction, owing to the improvement of the automobile torpedo, and there is reason to anticipate that a large vessel of more modern design would not have been destroyed at a single blow. But, however this may be, the indubitable fact remains that surface ships of war have not resisted explosion as it was thought that they would resist it. Every naval designer

and constructor will admit that the precautions which have hitherto been taken against mine and torpedo have proved inadequate.

It is already apparent that the battleship of the future will have to be designed on new lines. It may be that even the suggestions which are put forward by Mr. T. G. Owens in the paper which was published in "Cassier's Engineering Monthly" of May, 1914, will prove inadequate. It is possible that, while not abandoning the system of elaborate subdivision of bulkheads, some other means will have to be found for protecting the battleship against the torpedo, whether fired by submarine or destroyer.

In this connection it is interesting to recall that in the "United Service Magazine" of June, 1910, "Master Mariner" put forward a suggestion for rendering the battleship less liable to destruction from explosion. He controverted the opinion that it was impossible to produce a satisfactory form of external passive protection to a ship. He declared:

"We have for years accepted the general principle of such a defence in a half-hearted way, by providing all our large armored ships with a clumsy movable arrangement of nets, which give a very indifferent protection at the cost of effectually hampering all movement on the part of the ship. At that point we have stuck, save for minor improvements in the details of construction of the nets themselves and their appurtenances. But poor as this arrangement is, it was found sufficiently useful under the stress of war by Russia and Japan to retain its place in the equipment of their navies, and it is surely worth our while to follow up this lead experimentally at least. The main idea underlying any external defence evolved on this principle is not to resist the force of the explosion of a torpedo at the point of impact, but to *cause the explosion to take place at a sufficient distance from the hull of the ship to render it ineffective as regards serious injury to her buoyancy or her machinery.*

"If this idea is to be followed up to any purpose, however, we must be prepared for radical innovations in the external fittings—or even structure—of our ships, and it is just this point which largely accounts for our lack of progress. Any proposal which smacks of 'revolutionary' changes is regarded with suspicion in the Navy, and always has been. This extreme conservatism exists in all matters connected with the service, but perhaps in none so much as in those which affect naval ideas as to what properly constitutes a 'ship.' It is an historical fact that a picked committee of experienced flag officers and captains once officially condemned the introduction of steam as a most dangerous innovation in vessels of war. We should not be justified in blaming them in the light of our later knowledge, for the steam engine of those days was a very different affair to that of our own, and the views of these officers were colored—or, more strictly speaking, completely dominated—by the training of their whole lives to work under and accept conditions which this 'dangerous innovation' would undoubtedly change. But if their report had received the concurrence of the authorities the propelling power now in such effective use would never have been attained, except through the practical demonstration of its value in the Merchant Service and foreign navies. Similarly, the late Captain Cowper Coles—a man far ahead of his contemporaries in foresight and independence of judgment—had the utmost difficulty in persuading the Admiralty to convert the three-decker, *Royal Sovereign*, when on the stocks, into the radically different, but infinitely more serviceable, turret ship which she eventually became. In this instance it actually was the example of foreign countries which decided the Admiralty to act upon his suggestions. Cases such as these—and their name is legion—are instructive in proving that the common disinclination of the service to give due consideration to an entirely new idea, from an impartial standpoint, is by no means always justified.

"The innovations necessary to provide a ship with a complete and

efficient form of external defence against torpedoes would not involve, by any means, so drastic a change as the alterations whereby the *Royal Sovereign* was converted from an unprotected three-decker, carrying 100 guns, into an armored shell-proof turret ship carrying ten. But half measures would be a mistake, nevertheless, and no arrangement of nets dangling from the ends of swinging booms would mark a satisfactory advance, however great an improvement on our present equipment of that kind. The point to be realized is that to afford a real and durable protection under all conditions, an external defence would have to take the shape of a fixed and permanent structural addition to the ship. If we are prepared to accept the undoubted drawbacks and handicaps it would impose for the sake of the immense boon conferred in other directions, the provision of such a defence offers no insuperable difficulty. A screen of steel plates, slats, or bars answering the purpose could be devised without calling for any exceptional effort of constructive genius, and the security provided by some such arrangement would very amply counterbalance the disadvantages inseparable from its use. With our ideas wholly or mainly shaped by constant association with the ships of the present day, it is perhaps difficult for us to assimilate the notion of a ship with such an incumbrance surrounding her. But, in truth, the effort of imagination required is as nothing to that which the sailor of the early or middle nineteenth century would have been called upon to exert to foresee a *Dreadnought,* or even a *Devastation.*"

"Master Mariner" admitted that such a form of defence was not unaccompanied by drawbacks, but he held that the advantages that it would offer were too apparent to call for strenuous advocacy.

"The Capital Ship would at once resume the place held by her predecessor of a hundred years ago as Queen of the Seas, fearing nothing afloat by day or night, moving at will undeterred by any unseen danger. And the drawbacks themselves are on the surface, as it were, and sufficiently obvious to be foreseen and dealt with as far as practicable in advance. First of these is the docking question. A ship with a fixed screen would, of course, possess a much greater beam than one without, and require wider docks than any we possess. These would have to be built, unless open slipways were found preferable. And as the screen would prevent the use of docking shores, the ship herself would need to be constructed with a rectangular midship section to rest without shores on a "gridiron" dock, as flat-bottom steamers do in many parts of the world today. Then the screen would add, perhaps, a thousand or more tons to the weight a vessel would have to carry. Increased size of hull would meet this, and the advantage of a torpedo-proof defence would justify its existence, even if it weighed 20 per cent. of the ship's whole displacement. A reduction of her speed would be another unavoidable consequence. To what extent this would follow it is very difficult to foretell, but if the screen had openings allowing the free passage of the water in the fore-and-aft line—though too narrow to admit a torpedo—the loss of speed might not be very great. In any case this also could be met by increased size of hull allowing for greater engine power.

"Increased size of hull and engines would involve increased cost in the individual ship, no doubt, apart from the expense of the screen itself. But it would not involve an increase in the naval estimates as a whole. If we can produce ships to which the threat of the torpedo means little or nothing we shall be in a position to effect a very material reduction in the number of destroyers we lay down every year. Our destroyer flotillas are partly intended to safeguard our larger ships, by providing a force to attack hostile torpedo craft, and Admiral Bacon thinks that this reason for their existence will be emphasized in the future. If hostile torpedo craft are no longer to be feared, the necessity for this form of protection will vanish, and we shall need only to build such destroyers as are

required for purely offensive operations. Any great reduction in our annual output of destroyers would quite counterbalance the extra cost of screen-protected battleships."

The writer did not profess to offer proposals for a detailed design of the screen, admitting that that would fall within the scope of the naval constructor, but he, on the other hand, indicated what he regarded as essential.

"In the first place, then, it would have to be stout enough, as regards framework, to stand any kind of weather. To minimize the effect of pressures set up by movements of the ship, or the action of the waves, a cagelike structure of steel bars or slats would offer the advantages of reduced area of resistance if it could be made sufficiently strong to catch and hold, or explode, a torpedo. Any form of screen would, moreover, require to be quite independent of above-water fittings or supports liable to damage by gun-fire if it was to remain an effective protection after an action with other battleships. This, however, offers no great constructive difficulty. To extend the screen forward, ahead of the stem, would probably be superfluous, if it was carried into the stem itself from the supports on either bow, and the stem and forward compartments were strengthened. A torpedo striking the defence very far forward would, in such a case, explode comparatively near the shell of the ship no doubt, but opposite a small compartment, where the framework was specially constructed to minimize its effects. It would be essential also, to ensure that the screen was so constructed that no torpedoes could get behind it if fired from astern, as they sometimes do with any system of mere beam defence. Yet another important requirement would be that the screen should reduce the speed of the ship as little as possible. Generally speaking, an arrangement of horizontal bars would offer the least resistance, either direct or frictional, to forward movement, but experience would be necessary on this point before the best designs could be definitely ascertained. Lastly, the framework of the screen would have to be strong enough to allow the vessel to rest against it when lying alongside a jetty.

"It is not suggested, of course, that any form of screen strong enough to withstand the explosion of a torpedo altogether as regards damage to itself could be designed within practical limits as to weight. But it might be designed so that the damage was well localized and small as to general results. That is the case with the steel wire-net defences now in use, and is one of their few good points. If a hole was blown in a plate, or a few bars fractured—according as the screen was made of one or the other—the probability of a second torpedo finding its way exactly through the hole made by the first would be merely one of the very remote risks inseparable from the use of any design of war material intended to act as a shield.

"It may, perhaps, be argued that the introduction of such a form of protection would be immediately countered by an increase in the size of the torpedo, and very possibly, no doubt, that might be one of its first effects. But to be of any use the increase would require to be pronounced—in itself a great gain from a defensive standpoint. An increase would add greatly to the difficulty of handling torpedoes in destroyers and submarines, and reduce the numbers of the many torpedo craft, large or small, could carry. Torpedo craft themselves would then require to be bigger, and therefore fewer in number for a given financial outlay, and more easily sighted and dealt with by gunfire at night. We might, indeed, perhaps witness as a result of the introduction of defence screens a parallel to the enormous increase in the size of guns forced upon all navies by the introduction of armor. It may be that in this latter contest the gun is at last the victor, as Admiral Bacon thinks, but even if that is so, armor has immensely added to the difficulties with which the gun has had to contend, and severely limited the number of effective guns a ship of the line can carry."

In the light of what has occurred during the present war, all who are concerned in the creation of naval power will be interested to read again the suggestions of this "practical seaman," as he described himself.

It may be that the battleship of the future will be provided with some such screen as this writer has indicated; the war has certainly shown that an external defence of this character would be a great source of strength. It may be that, in accordance with American policy, each unit will be much bigger than anything hitherto known in Europe. It is probable that there will be considerable development of the scheme for the subdivision of the hull, and it is possible that the ship will be provided with a bow somewhat resembling that which has been given to the newest Russian battleships. This would strengthen the large ship if at any time she had to ram an enemy's larger seagoing submarine when running on the surface. It is probable also that the battleship of the future will be almost as swift as the vessels which are now known as battle cruisers, since speed and the use of the helm have been shown to be the best defence against the torpedo or the submarine. In any case we may regard one thing as certain, and that is that naval constructors will put up a strenuous fight for the survival of the large-gun ship, with its suggestion of power so patent in peace, when diplomacy fights our battles, and there can be little doubt that as a result of their labors the battleship will remain the supreme unit of naval power.—"Cassier's Engineering Monthly."

THE APPLICABILITY OF ELECTRICAL PROPULSION TO BATTLESHIPS, TOGETHER WITH THE EXPERIENCE GAINED WITH IT ON THE *JUPITER*.

By Lieutenant S. M. Robinson, U. S. N.

ABSTRACT.

The object of this paper is to show the best method of ship propulsion to be applied to battleships. It has been attempted to keep out all matters that do not bear directly on this one point. The *Jupiter* has been introduced merely to show the reliability of the apparatus that it is proposed to use. The Navy Department has authorized an electrical installation for the new battleship *California*, and it is believed that she will mark the beginning of a new era in marine engineering.

Briefly, the machinery for a battleship would consist of two turbo-generators running at a maximum speed of about 2,000 revolutions and generating current at about 3,000 volts, two switchboards, and four induction motors. The latter would be arranged with one on each of four shafts. The motors would be of the double squirrel-cage type and the stators would be fitted with pole changers which would give the motors two different numbers of poles and consequently two speed reductions. The motors would have two independent squirrel-cage windings, the outer one having conductors of high resistance and the inner one conductors of low resistance. At high frequencies, such as would obtain in the rotor when starting up or backing, the inner winding takes practically no current due to its high resistance under these conditions; therefore the high-resistance winding on the outside is the only one in operation and this insures a large torque for starting or backing. When running close to synchronous speed, the resistance of the inner winding is much reduced and it then operates like any ordinary squirrel-cage motor.

In choosing a method of propulsion for battleships, there are six points to be considered. They are, in order of their importance: (1) Reliability, (2) maneuvering qualities, (3) economy, (4) space occupied, (5) weight, (6) care and upkeep.

RELIABILITY.

Taking these points in their order, the first to be considered would be reliability. The reliability of induction motors and large high-speed turbo-generators for land use has been well known for some time, but up to about one and one-half years ago had not been demonstrated on board ship. However, experience at sea with them has not developed any trouble, and their reliability is now unquestioned. There are several things that go to make an electric installation more reliable than any other. First, the installation is in duplicate throughout and the breaking down of one engine does not affect the ship except at high speed; it might be said that this is true of other installations, but it is not true in the same sense nor in the same degree that it is with the electric drive. For example, if one turbo-generator breaks down, the ship can still run in a perfectly normal manner up to a speed of about 19 knots. This would be impossible with any other mode of propulsion; even at speeds within the power of one engine on a twin-screw ship the maneuvering qualities would become so bad as to handicap the ship; in fact, a twin-screw ship operating with one engine would be able to reach port safely but would be of very little use in battle, whereas an electrically-driven ship, operating with one turbine, would be just as good as any ship up to a speed of about 19 knots.

Then, too, there is the question of auxiliaries; with other forms of propulsion, if the auxiliaries in one engine room break down, that engine room may be almost entirely put out of commission. Of course the main air and circulating pumps are cross-connected, but when operating that way they are not very satisfactory, and I have seen a battleship forced to stop because the forced-lubrication pumps in the starboard engine room broke down. If the ship had gone ahead with the port turbines, the starboard turbines would have revolved and burned out the bearings, so that it was necessary to stop the ship and repair pumps; with electric drive it would be a simple matter to shift to the other engine room and make repairs without stopping.

There is one thing that makes the installation more reliable than other forms of turbine drive, and that is the fact that the turbine revolves in the same direction all the time. The importance of this cannot be overestimated, as it is believed by operating engineers that the greater amount of blading trouble that ships have had is nearly always due to the distortion that occurs when backing. There is also one other advantage when compared with reciprocating engines, and that is that the turbines would be less susceptible to damage by water when the boilers are priming. This fact has been thoroughly demonstrated by experience on the *Jupiter*.

MANEUVERING.

As regards maneuvering qualities, it is believed that the electric drive is far superior to any other method. This point will be taken up more in detail when the *Jupiter's* installation is discussed. It is rather difficult to describe these advantages on paper, but very easy to appreciate when you see the machinery working. Instead of big, heavy throttles to open and close, there are light, easily-handled oil switches, and a speed controller that can be handled with one finger. The engine-room watch required for a battleship would be just half what it would be with other means of propulsion, as one engine room would be idle practically all the time. In a rough sea there is no racing, with its attendant strains on machinery and on the personnel on watch. Any desired speed can be very quickly attained. The speed can be very accurately maintained and without any effort on the part of the personnel. These last two points are of very great importance on battleships when maneuvering in forma-

tion. The stand-by qualities are also superior to those of other installations, for at a very small expense in the way of steam the main turbine can be kept running very slowly and the engine room is then ready to answer signals at any time; this might be of great importance to a battleship. The backing qualities of this installation are also superior to other forms, particularly turbine installations. It is possible to attain full power in the astern direction.

ECONOMY.

In considering the question of economy, we have reached the point which first suggested the use of electricity for the purpose of propulsion. None of the older forms of propulsion, such as reciprocating engines or direct-connected turbines, can compare at all favorably with this method, the gain in economy being over 20 per cent. at high and cruising speeds. The only other method of propulsion that would appear to compete with this method in economy would seem to be the combination of high-speed turbines and reduction gears. The loss in the latter amounts to about 2 per cent., while in the electric-reduction gear the losses are from 8 to 9 per cent. Mechanical reduction gears have been developed to a high degree, and it is very probable that in quite a number of cases the mechanical gears would be preferable to the electric drive, but as this paper is limited to a discussion of battleships that subject will not be touched.

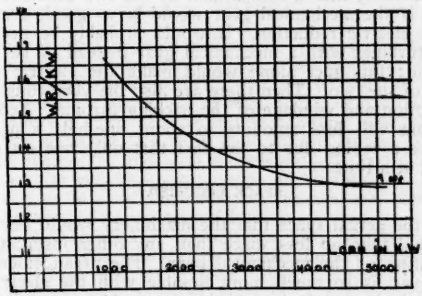


FIG. 1.—4,000 K.W. TURBINE, U. S. S. JUPITER.

For battleships I do not believe there is any question of the relative economy of the two methods—the electric drive is far superior. The electric reduction method possesses two inherent advantages that the mechanical method cannot overcome. First, the electric installation uses only one turbine at low powers; second, the induction motors are fitted with pole changers which allow the turbine to be run at normal speed with the ship cruising at low speed—in other words, the electric drive permits of two speed reductions while the mechanical gear has only one. These two advantages exist no matter how the two installations may be laid out, and they far outweigh the difference in the losses of the two methods. To show just how great these advantages are, two curves are shown. Fig. 1 shows the *Jupiter's* turbine operating under varying loads and Fig. 2 shows the turbine operating under varying speeds (and also loads). The load curve does not really show how very bad the conditions are for a battleship, as in that case the power at 12 knots is only about one-seventh what it is at 21 knots and the curve shown does not give so great a per cent. of reduction. It will also be seen that the speed curve is very steep at the low speeds and shows the bad effect of reducing tur-

bine speed very greatly. As nearly all the cruising of a battleship is done at fairly low speeds, it is evident that the electric drive will be more economical than the mechanical gear.

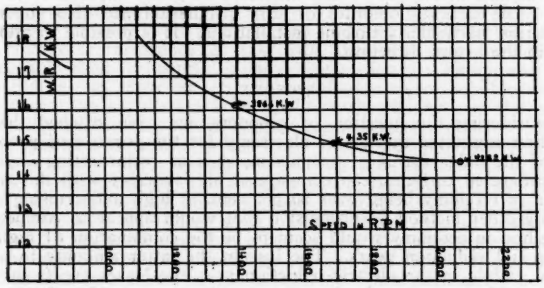


FIG. 2.—4,000 K.W. TURBINE U. S. S. JUPITER.

In addition to the two advantages just stated, there are a number of other things entering into a comparison of the two methods that make it very doubtful if the mechanical gear would be as good, even at the high speeds, as the electric reduction. It would probably be necessary to use at least four turbines with a mechanical gear instead of two, as with the electric method; this fact alone would make the electric reduction the more efficient of the two. Then there are also the very considerable losses due to the friction and windage of the backing turbine. According to Sir Charles Parsons this loss amounts to about one-half a per cent. Also there would be a saving due to the fact that only one set of auxiliaries would be used at a time.

SPACE OCCUPIED.

As regards the actual space that the machinery would occupy, the electric drive would take up less space than any other installation, with the possible exception of the mechanical gear. The arrangement of the machinery, however, is so much more flexible with the electric drive than with other methods that it is probable it would occupy less space than would the gears. It lends itself very readily to watertight subdivision.

WEIGHT.

The next point to be considered is that of weight, and here again the electric drive is superior to any other method with the possible exception of mechanical gears. It is rather difficult to say exactly how the two methods would compare either as regards space or weight, as a great deal would depend on the number of turbines used with the mechanical gear in order to get 30,000 shaft horsepower. However, if the largest sizes of geared turbines now at sea are any guide, the weight of the electric drive would be less than the weight of the geared turbine.

CARE AND UPKEEP.

As regards care and upkeep, the electric drive is greatly superior to either reciprocating engines or direct-connected turbines, also due to the fact that the turbines do not have to reverse, it would be superior to the geared drive in that it would have less blading trouble. Either of the two latter methods, however, is very satisfactory in this respect, as a high-

speed turbine is so small that it is easily handled and repaired by the ship's mechanics.

This completes the case of the electric drive for battleships; all of the points have been considered and in every case it has been seen that it has no superior. There are, however, some points that have been made against electric propulsion, and these will be taken up before proceeding to a discussion of the *Jupiter's* installation. First, there is the danger from large quantities of water in the engine room; however, this danger is more fancied than real, as all the wiring could be placed well overhead, being taken out of the tops of the motors and generators. The generators could be placed high enough to insure their safety and the motors could be placed in watertight pits so that the engine room could have enough water in it to put the auxiliaries out of commission before reaching the main engines. The next point is that, when operating with one turbine, all motors must run at the same speed if they run at all; this fact has been found to be no handicap in actual operation. The next point is that, in turning, the inboard screw does not slow down; this slightly increases the turning circle, but does not increase the space necessary to turn in, as the inboard screw can always be stopped or backed.

The equipment on the *Jupiter* is similar to that which would be used on a battleship, so it offers a good example of many points that have been advanced in favor of the electric drive.

U. S. S. "JUPITER."

The *Jupiter* has been in commission over a year and a half. During that time she has conducted two official trials and has carried on the usual routine work of a navy collier. She has steamed about 14,000 miles and has been handled a great deal around docks, in narrow channels, and other places where a great deal of engine handling was required. About one-half of the steaming has been done in the tropics with circulating water over 80 degrees F. and with correspondingly poor vacuum, so that the economy of the ship is known under all conditions. The fuel economy has proved to be excellent, being, on the average, about 25 per cent. better than the best of her sister colliers.

During the whole period of commission, two repairs have been made to the main engine. The first was to reblade the first stage of the turbine. This work was done entirely by the ship's mechanics. The first-stage blading was injured by a bolthead from the segment carrying the fixed blading. The bolt was broken off, probably through having been set up too hard while assembling. These bolts were all tap bolts and have been replaced by filister head screws with countersunk heads, and a repetition of the accident would not be possible. The accident, however, was in no way peculiar to the electric drive, as it might very well have happened to any other engine. The other repair was to replace one of the porcelain cylinders which carry the resistance; this cylinder was cracked when the ship went into dry-dock, but it was never discovered whether the cracking was due to the oiler putting undue pressure on the cylinder or due to some strain brought on it when the ship settled on the keel blocks. At any rate, the damage was repaired by two machinists in about two hours.

The amount of work expended in keeping the equipment in condition has been very small. After coming in from a run the turbine clearances are taken to see if they have changed; and the motor clearances are also checked; there has been no change in either of these clearances up to date. Before getting under way the holding-down bolts of the turbine are gone over to see if they are tight, the slip rings on the motor of the generator are examined to see if they are clean, and all insulators are also examined for cleanliness, all connections are generally gone over to make sure they are tight, the oil-switch boxes are examined to see if they have

the proper amount of oil, and the governor control-valve springs are tested to see if they have the proper tension. After starting the turbine, the emergency trip is tested. In port the oil pump is run once a week to force oil through the turbine bearings and the motor shafts are jacked daily. Due to the fact that the main condenser is used a great deal (the auxiliary condenser being too small to handle the coaling winches), the small pump for draining the turbine casing is run for a few minutes each day when in port to make sure that no water may be allowed to accumulate in the turbine.

In operation the *Jupiter's* engines have been highly satisfactory. There has been only one time when anything has happened during the handling of the engines and that was the tripping out of an exciter. The lighting set was immediately put on for exciting and the engines were ready to use again in about one and one-half minutes. If such an accident were to happen again it would take even less time, as the men are more familiar with the installation. At the time the accident occurred the ship had just left the navy yard for the first time.

The handling of the engines has been proved more than once; the ship has been handled a great deal in narrow waters and around docks. She steers very badly at times, and the quick response of the engines has more than once helped in getting out of difficulties. The engines have been used to swing ship for compass deviation without putting any way on the ship at all, the total space used for swinging being little more than the ship's length.

The ability of the turbine to stand severe abuse from water has been demonstrated several times. There is no separator on the main steam line, and several times the boilers have primed and carried considerable water over into the turbine. This was particularly noticeable during dock trials, when it was impossible to properly handle the boilers. The only indication the turbine gave was an increase in the first-stage pressure and a rattle in the casing as the water was hurled through at a high rate of speed, but the turbine blading showed no signs of bad effects from this.

The backing qualities of the engines have proved to be all that could be desired; if the ship is cruising with the resistances in, the time taken for reversing is practically nothing at all; if the resistances are out, it takes a few seconds—not more than three.

When underway the engine room is very cool, due to the fact that the generator is fitted with air impellers at each end which take their suction from the engine room, thus insuring a good circulation of air.

After all, the greatest test of the satisfactory working of any machinery is whether the men who are actually handling it and caring for it are pleased with it. If this test applies to the *Jupiter's* machinery it certainly is an unqualified success. In particular is this true if the matter is referred to the coal passers in the fireroom who have to handle much less coal than do the men on sister ships. The ship can make her contract speed of 14 knots without using forced draft at all.—"International Marine Engineering."

GEARED TURBINES FOR SHIP PROPULSION.

In the course of their paper entitled "Geared Turbines for Ship Propulsion" which was read before a recent meeting of the Institution of Engineers and Shipbuilders in Scotland, the authors, Messrs. W. D. McLaren and G. M. Welsh, devoted some attention to the subject of the gears forming part of the installation of turbine propulsive machinery on board ship. They pointed out that very little experience has yet accumulated to enable a decision to be derived at for selecting the maximum

permissible load between the wheel teeth. The teeth being of involute form have a curvature of face dependent on the diameter of the base circle and hence the teeth on a small pinion offer a less extensive bearing surface than those on a large one. Of course, theoretically, the teeth have only one point of contact, but in actual work, however, they do not come into metallic contact, having a thin film of oil between them. Hence the flatter the curvature of the teeth the larger the supporting oil pad. There can be very little doubt regarding the retention of this film of oil while the teeth engage, when it is remembered that the period of engagement is usually less than one-thousandth of a second. Another argument for the adoption of a greater intensity of pressure between the teeth for large pinions is that the effective length of the oil contact film is longer than for small pinions. In their conclusions the authors point out that in all the cases which they have considered of steamers equipped with geared turbines an advantage in coal consumption was shown at full power over the reciprocating or direct turbine type of machinery.—"Shipbuilding and Shipping Record."

FIRST STUMPF UNA-FLOW ENGINE BUILT IN AMERICA.

The development of the una-flow engine promises much for the future of the steam prime mover. It is therefore of interest to note the introduction of this engine into America. The Ames Iron Works have recently constructed the first una-flow engine, to be made in this country with the approval of Prof. Stumpf.

As is commonly known, the una-flow engine has effected an increased economy because of reduced cylinder condensation losses. This is due to the fact that the steam is exhausted at the other end of the stroke from that at which admission occurs. Hence the steam in entering is not passed over the cooler end of the cylinder, lowered, at the end of the stroke, to the temperature of the low-pressure steam. By eliminating the loss between cylinders of a compound or triple-expansion engine, the same power may be developed with a una-flow engine having cylinder dimensions materially less than those of the low-pressure cylinder of a multiple-expansion engine. The Stumpf engine built by the Ames Company shows a reduction of 20 per cent. in this respect.

The results of tests on this engine recently published, show very significant results. The engine is rated at 100 kw.; its dimensions are 15 x 16 inches, and its speed is 250 r.p.m. The best economies are 12.5 pounds of steam per I.H.P. hour condensing, and 16.8 pounds non-condensing (superheated steam in both cases). These economies are indeed remarkable for an engine of such small capacity, but the most significant feature of the performance lies in the flatness of the water-rate curves. In varying the load from almost zero to 150 per cent. of rating the greatest variation is about 2.5 pounds per I.H.P. hour. When the water-rate curves of the best multiple-expansion engines are considered, these results appear to be almost revolutionary.—"Sibley Journal of Engineering."

THE JUNKERS OIL ENGINE.

By Dr. F. E. Junge.

In an age of intensive cultivation, when efficiency is the controlling factor of human affairs, and the observation of its rules secures to all, who want to profit, increasing mastery over the means of life, it is natural and necessary that efforts of advance, as in other fields, would also be made in the realm of power generation, which is the foundation of the indus-

trial arts. Efforts certainly have been made and advances effected, some in the traditional modes of steam power generation, and some in the novel field of internal combustion.

While for purposes of large-scale power production and transmission, the steam turbine, owing to its inherent advantages, has attained and will always retain its distinct usefulness, especially when coal is the impelling fuel and stationary plants are concerned, a different outlook presents itself in those fields of application where economy, capacity and weight are limiting conditions, and where, in addition to the nature of the plant, the nature of the fuel—heat density, value, storage, etc.—must be considered.

To the qualities of liquid fuel, offering numerous advantages over solid combustibles the rapid development of oil power during the last decade must be attributed. Owing to the fact that the fuel is liquid and can be evaporated, atomized or sprayed, a very intimate mixture of combustible matter and air before and during combustion results. This, in turn, enables those operations for which the steam prime mover requires a boiler, to be performed and terminated in the power cylinder itself. Not by indirect contact—heating and expansion—but by direct contact of internal combustion is the heat energy of the fuel transformed into work. As heat influx and efflux are confined to the working cylinder—a comparatively small space—temperatures are increased tenfold, while heat losses are diminished, superior fuel consumption, economy and sootless combustion being the result.

The first stage of oil-engine development is characterized by the practice of adopting methods and using elements of machine design which had proved successful in the generation of gas power, without attempting to adjust them to the varied requirements of liquid fuels. The Otto engine and the four-cycle mode of operation were the Alpha and Omega of the earlier art. Nothing but conventional forms and ideas were employed. The results accordingly were disappointing, not only in regard to mechanical operation, but also with reference to the economic results, because comparisons of thermal efficiency, etc., were restricted to the steam and oil engines, respectively, and did not include the boiler plant and its auxiliaries. The greatest drawback of earlier development was that only high-grade oils could be used in the heat engine, while medium grades, even petroleum, gave endless trouble. Crude oils, of which we have large quantities all over the world, and residue oils remaining available as by-products of distillation, could not be used at all.

The second step in the evolution of oil power, especially in the direction of an enlarged range of application, was made by the invention of the Diesel process. It is characterized by the compression of air in the power cylinder to such temperatures that the fuel will ignite when injected into it in a finely atomized state. Though the application of the Diesel process in practice was considerably retarded by difficulties of mechanical character, which are not wholly overcome even today, it has brought about results, thermal as well as economic, which were previously deemed impossible. It has opened new avenues of thought and has called into being superior rules of workmanship which, though conventional in form, were revolutionary in effect. But the Diesel engine, pushed after the expiration of the Diesel patents by manufacturers all over the world, had soon reached a state of development beyond which further progress becomes impossible, owing to fundamental limitations which are associated with the application of the (new) Diesel process in the (old) familiar form of gas engine of the Otto type. Diesel did not recognize the mechanical limitations of existing heat engines and their bearing on the essential features of internal combustion. Nor did he conceive the idea of evolving new forms or elements of machinery, which would permit him to attain all the possibilities inherent in his process. Capacity, maneuvering, economy—in short, the essential conditions of efficient locomotion—had

reached their highest mark in the conventional Diesel engine. No further progress was possible unless the accepted principles of engine design were discarded.

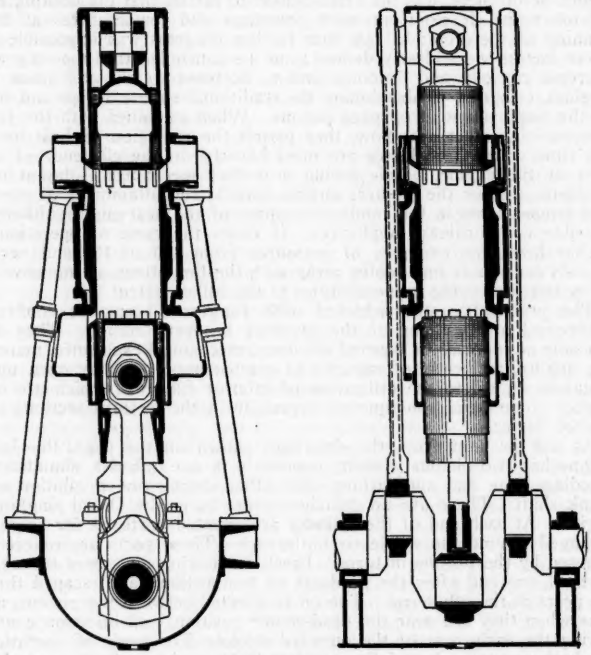
A new step in advance in the generation of oil power was made by the discovery and application of the Junkers process of perfect heat flow. Contrary to established practice, it effects compression heating, and expansion of the charge in two directions, opposite to each other, realizing high initial and low end pressures, whereby the mechanical and thermal deficiencies of the Diesel process are eliminated and its economic efficiency is increased. Prof. Junkers, known by the calorimeter and other devices which he invented, was the first scientist to realize that the limiting factors of oil-engine development were pressures and temperatures at the beginning of the cycle; he saw that further progress was impossible unless these factors were clearly defined; and he concluded that the only way to increase capacity and economy and to decrease weight and space of oil engines, consisted in abandoning the traditional engine design and turning to the employment of opposed pistons. When combined with the Junkers process of perfect heat flow, they permit the reduction of heat losses at the time when these losses are most harmful to the efficiency of operation of the engine, beside giving a perfect mechanical solution of the problem. Hence the Junkers engine permits the attainment of pressures and temperatures in the combustion space of the heat engine hitherto impossible with ordinary appliances. It raises the cycle of operation to a higher level, for example, of pressures from 100 to 150 and even 200 pounds per square inch, doing away with the limitations of intensive operation and preserving its possibilities to the fullest extent.

The practical results achieved with Junkers oil engines confirm the theoretical anticipations of the inventor in every respect. They reveal not only an increase of thermal efficiency, mechanical excellence, maneuvering quality, and ratio of capacity to compactness, but they open up new vistas in regard to the utilization of inferior fuel oils, which are of the utmost commercial consequence, especially in the western sections of the United States.

As will be seen from the drawings, shown on the page, the Junkers engine has two pistons working oppositely in one cylinder, simultaneously receding from and approaching each other during one revolution of the crank shaft. There are no cylinder covers as in the Diesel single-piston engine. At each end of the cylinder are situated ports, as far as possible arranged around the whole circumference. These ports are covered and exposed by the pistons in turns. Fresh scavenging air enters through the ports at one end after the products of combustion have escaped through the ports at the other end. The oil is injected between the pistons, at the time when they are near the dead-center position, and injection continues during the early part of the outward stroke. The mode of operation of the Junkers engine is as follows: when the two pistons have reached their outermost position in the cylinder, clean scavenging air delivered by air pumps enters through the ports at one end of the cylinder and drives the products of combustion in front of it out through the ports at the other end. The cylinder is now filled with clean air. On the in-stroke the pistons approach each other and compress the air between them to such a degree that the oil on being injected immediately ignites and burns, the resulting pressure driving the pistons outward until they uncover the outlet and inlet ports simultaneously, as described.

This mode of construction and operation results in the following general advantages: cylinder covers which in large oil engines give trouble on account of their complicated forms, are absent in the Junkers engine, as the cylinder is closed at both ends by the opposite pistons, which can be easily removed when necessary. The pressures arising in the power cylinder are directly transmitted to the crank shaft through the piston

rods, without the intervention of passive machine parts, so that the frame, bed plate, and main bearings are relieved of stress. The cylinders have no longitudinal stress. There are no stuffing boxes, which are unsatisfactory at high pressures and temperatures. The division of the stroke to two opposed pistons permits the adoption of a long stroke and wide range of expansion with only a low piston speed. Thus a long cylinder of comparatively small diameter is obtained, which in its turn permits of an advantageous form of combustion chamber and good scavenging. Finally, the arrangement of opposed pistons results in a good balance and consequently quiet running.



PISTON OPERATIONS IN THE JUNKERS OIL ENGINE.

Considering especially the advantages of the double stroke, enabling a more perfect ratio of compression and expansion, the main feature is the increased capacity. Given the same height of engine, the same number of revolutions and the same mean pressures, obtained from the respective indicator cards, the Junkers engine develops 75 per cent. more power than the traditional system. This fact is of the utmost importance in all cases when space and weight are limiting conditions. Modern fighting craft, for example, require the utmost concentration of power compatible with efficiency. As high as 20,000 horsepower is required in modern submarine construction, and the available room is confined to the utmost. Similar conditions obtain in the propulsion of air craft, where weight and fuel economy—beside maneuvering capacity and certainty of operation, de-

termine the usefulness of the prime mover. None but the double-piston arrangement can meet the exacting requirements of modern locomotion.

Other advantages are: (1) comparatively small area of the clearance space, preventing heat losses, permitting the attainment of high mean pressures (average 150 pounds per square inch), slow speeds, quick starting of the engine from cold, low fuel consumption per unit output, and ability to use all grades of fuel oils; (2) better scavenging, which produces high mean pressures, reduces the consumption of scavenging air, and decreases the power absorbed for pumping work; (3) perfect mixing of air and fuel in the power cylinder, giving good combustion, eliminating residues, increasing fuel economy, and extending range of application of inferior oils; (4) enlarged crank radius and elastic crank shaft; (5) reduction of losses in the moving machine parts, hence increased mechanical efficiency; (6) improved ratio of mean and maximum pressure, enabling better utilization of all parts which are designed to withstand the highest stresses occurring in the process; (7) reduction of weight and cost per unit of output.

A most important feature, especially in regard to the propulsion of vehicles and craft, consists in the ability to carry overloads of 50 per cent. and more, requiring no auxiliaries, but the throttling of the exhaust outlet. The Junkers engine has stretched the upper limit of oil-power capacity to the threefold of the values obtained by existing systems. Assuming that the greatest shaft diameter attainable is 600 millimeters, and therefore taking the limit of cylinder diameter at 900 millimeters, the following powers per shaft for six working cylinders are obtained as maximum: 4-cycle Diesel engine, 2,750 horsepower; 2-cycle Diesel engine, 4,500 horsepower; 2-cycle Junkers engine, 7,000 horsepower; 2-cycle Junkers tandem engine, 14,000 horsepower. Under conditions as they prevail in America, and especially in the western sections of the United States, the chief advantages are: simplicity of construction, absence of complicated valves, etc.,—these being only two moving parts in the power cylinder—an arrangement enabling cheap manufacture and fool-proof operation, before all rendering the engine capable of using inferior grades of oil, such as are abundant in California and Mexico. In the accompanying table the results of fuel-consumption trials with various grades of oil are presented, together with the analysis of the oils used. It is seen that the consumption of crude Californian and Mexican oils is only 0.48 pound per brake horsepower hour, and the thermal efficiency of the process 44 per cent., as much as 48 per cent. of asphaltum being contained in the fuel. The lower speed limit at which self-ignition takes place is between 30 and 60 revolutions per minute.

Table Showing Results of Fuel Consumption Trials in Junkers Engines.

Analysis of Oil.	Gas Oil.	Pacura.	California.	Mexican.	Masut	Tar.
Cal. Value B.T.U. per lb....	18,000		17,400	17,460	17,800	15,950
Carbon, per cent.....	86.9		84.0	83.2	85.6	90.1
Hydrogen, per cent.....	12.2		11.1	11.3	12.1	7.1
Sulphur, per cent.....	0.71		0.87	2.43	0.05	0.63
Oxygen, per cent.....	0.16		3.93	2.90	0.72	1.66
Incombustibles, per cent.....	0.00		0.13	0.14	1.43	0.50
Specific gravity	0.85	0.90–0.98	0.86	0.94	0.90	1.07
Viscosity	1.14		6.41	4.11	19.9	1.66
Flash point, deg. Cent.....	80	140	137		113	98
Asphaltum, per cent.....			48.1	45.6		
Results						
Mean ind. pressure lbs. per sq. in. 154.4		161.7	155.8	147.0	158.6	147.0
Thermal efficiency, per cent...	48.0	46.0	44.7	44.3	46.5	45.0
Revolutions per minute.....200		205	200	200	200	200
Brake and horsepower.....160			151	145		144
Fuel consumption, lbs. per B.H.P. per hour.....	0.427*	0.440	0.480	0.480	0.305**	0.480

* Referred to fuel having a calorific value of 18,000 B.t.u. per pound.
**Referred to indicated horsepower.

While the Junkers engine was at first exclusively built for stationary power plants and for driving vessels, it is of late being adapted to the propulsion of locomotives, automobiles and air craft. The Junkers engine is now being constructed by the leading ship builders and manufacturers all over the world, as well as at the Junkers works in Aachen and Magdeburg. Among other builders are the Allegemeine Elektrizitats Gesellschaft, Germany, Doxford & Sons, England, Nobel and Nornowo, Russia, Dujardin, France, and the General Electric Company, United States.—"The Engineering Magazine."

REPORT ON TEST OF DIESEL ENGINE PLANT OF THE NATIONAL ICE AND COLD STORAGE COMPANY, SAN FRANCISCO, CAL.

By J. B. Howell, Member.

Report on test made to determine the fuel consumption of a 200-brake-horsepower Diesel engine at the plant of the National Ice and Cold Storage Company, at Union and Battery Streets, San Francisco, October 12, 1914.

This test was made to verify the rate of fuel consumption guaranteed by the engine builder.

DESCRIPTION OF PLANT.

The engine tested was a 4-cylinder, 4-cycle, vertical Diesel engine, having a rated capacity of 200 brake-horsepower at 250 r.p.m., manufactured by the Dow Pump and Diesel Engine Company of San Francisco.

The engine was equipped with an extension shaft carrying two belt wheels, by which it was belted to both an ammonia compressor of 100 tons' refrigerating capacity, and to an electrical generator of 65-kw. capacity, at 1,200 r.p.m., 250-volt direct current.

When running at full load the engine carried the ammonia compressor and the generator loads.

During the test made at reduced loads the generator was allowed to run without load.

The air compressor supplying injection and starting air is a Reavell, 3-cylinder, 3-stage compressor, driven directly from an overhung crank at one end of the engine crankshaft.

The principal dimensions of the engine are as follows:

Cylinder diameter	12.01 inches; area 113.28 square inches.
Stroke	18.10 inches.
Rated speed	250 r.p.m.
Piston speed	250 r.p.m. = 754.16 feet per minute.

At 250 r.p.m., each pound mean effective pressure on piston produced .6472 indicated horsepower in one cylinder.

Guaranteed fuel consumption by makers were made as follows:

At 50 per cent. load	.50 pound per b.h.p. hr.
At 75 per cent. load	.45 pound per b.h.p. hr.
At 100 per cent. load	.41 pound per b.h.p. hr.

The fuel specified by the builders upon which the above guarantees were made called for air oil of the following characteristics:

Gravity, not under	24 degrees Beaume.
Flashpoint, not under	180 degrees F. open cup.
Burning point, not under	235 degrees F.
Asphalt, not over	25 per cent.
Sulphur, not over	.75 per cent.
Heat value, not over	19,200 B.T.U. per pound.

Fuel used as analyzed by Smith Emery and Co., of San Francisco, as follows:

Specific Gravity (23.93 degrees Beaume)	.9095
Water, per cent	.08
Sand	none.
Flashpoint (open cup) degrees F	212
Burning point, degrees F	235
Viscosity (Tagliabue, water, 60°), degrees	81.6
Sulphur, per cent	.44
Asphalt, "E Grade," by distillation, per cent	23.2
Heat value lower (water incondensed) B.T.U	18,407
Heat value higher (water condensed) B.T.U	19,649

Value of asphalt content indefinite, as there are several grades.

CONDITIONS OF TEST.

The test runs consisted of a 6-hour run at full load, and a 2-hour run at approximately 75 per cent. load, an interval of 30 minutes elapsing between the runs.

Owing to the difficulty of accurately determining the power absorbed by the ammonia compressor, and the efficiencies of the belts, and the losses in generating electricity, it was agreed by the parties concerned to determine the indicated horsepower directly from the engine, and arrive at the brake horsepower by the mechanical efficiency, which was to be taken from reliable tests on Diesel engines.

These mechanical efficiencies are given herewith and are obtained from test data published by Mr. R. Royds, J. W. Campbell, M. C. E., and Mr. Longridge, M. Inst. C. E.; also from the Encyclopedia Britannica.

The data given herewith are obtained from the curve sheets attached hereto.

Loads, per cent.	B.H.P.	Friction H.P.	Mech. Efficiency, per cent.
60	120	48	69.6
70	140	51	72.55
80	160	54	74.5
90	180	56	76.3
100	200	60	77.7
110	220	62	78.9

During the test the loading was kept within a range which did not exceed 6 per cent. above the mean nor fall below 5 per cent. under full loading.

During the reduced-load test the range was kept within 2 per cent. of the mean.

Indicator and Cards.—Indicator diagrams were taken from each cylinder every 15 minutes, and as there were four cylinders the turning of cards was so arranged that not more than 4 minutes elapsed without a card being taken from some one of the cylinders.

Two indicators were used, and they were applied alternately to each cylinder, so that a complete set of cards was obtained for each indicator from all cylinders.

One of the indicators was made by the Lunkin Co., Ltd., of London, and one made by the American Steam Gauge and Valve Mfg. Co. Both of these indicators were calibrated at the University of California. The Lunkin indicator having a constant of 344 to multiply the average height of card to obtain the M.E.P. The American steam gauge having a constant 335 to multiply the average height of the card to obtain the M.H.P.

Measurement of Indicator Cards.—The measurement of the areas of each indicator card was done by two operators using different planimeters, and the length of each card was also separately measured by the two operators, and their results agreed.

Measurement of Fuel.—The fuel was accurately weighted on tested scales, and poured into a small tank located above the engine.

Cooling Water.—A record of the supply and outlet temperatures of the cooling water was kept but the amount used was not recorded, as the water is used over and over again. The supply temperature averaged 80 degrees F., and the outlet temperature ranged from 135 degrees to 152 degrees F.

Ammonia Compressor Data.—Indicator cards were taken from the ammonia compressors every 15 minutes, but no attempt was made to calculate the horsepower from these cards, as the results would have been inaccurate due to unknown factors.

Electrical Generator Data.—During the 6-hour full-load run an accurate record of the electrical power generated was kept but was not used, for an accurate check on the power developed due to unknown factors.

Injection Air.—The injection-air pressure during the 6-hour full-load run ranged closely around 925 pounds per square inch.

During the 2-hour run at reduced load the pressure remained steady at 860 pounds per square inch.

Exhaust Gases.—No attempt was made to analyze or take the temperature of the exhaust gases, but the clearness of the exhaust from each cylinder was observed. Only one of the cylinders showed signs of incomplete combustion.

Results.—The results are tabulated herein, on the 6-hour full-load run the American Steam Gauge Indicator showed signs of faulty action and the cards taken by this indicator were thrown out.

On the 2-hour reduced-load run a loose drive on this indicator was repaired and cards from both indicators were used.

G. K. Davol, consulting engineer, students from the University of California, and J. B. Howell, representing the engine builders, conducted the test.

ENGINE No. 2.—FULL-LOAD TRIAL, 6-HOURS, 9 A. M. TO 3 P. M., OCT. 12, 1914.

Card Nos. Cyls. 1 & 2	Cyls. 3 & 4	Cyl. No. 1. Area	Cyl. No. 1. Length	Cyl. No. 2. Area	Cyl. No. 2. Length	Cyl. No. 3. Area	Cyl. No. 3. Length	Cyl. No. 4. Area	Cyl. No. 4. Length
2	1	.820	2.80	.900	2.82	.770	2.85	.950	2.82
4	3	.765	2.80	.860	2.82	.840	2.84	.935	2.84
6	5	.728	2.81	.770	2.82	.880	2.85	.895	2.81
8	7	.770	2.82	.870	2.80	.805	2.84	.870	2.82
10	9	.695	2.80	.870	2.82	.810	2.84	.800	2.83
12	11	.690	2.82	.920	2.83	.830	2.84	.860	2.80
14	13	.735	2.80	.935	2.82	.830	2.82	.795	2.82
16	15	.700	2.82	.900	2.82	.830	2.82	.820	2.82
18	17	.690	2.82	.845	2.80	.860	2.81	.840	2.80
20	19	.750	2.82	.880	2.81	.835	2.82	.805	2.80
22	21	.710	2.82	.845	2.80	.880	2.83	.850	2.82
24	23	.730	2.86	.850	2.81	.825	2.84	.800	2.82
		8.783	33.77	10.445	33.77	9.995	33.98	10.220	33.82
M.E.P., lbs.		89.467		106.390		101.184		103.95	

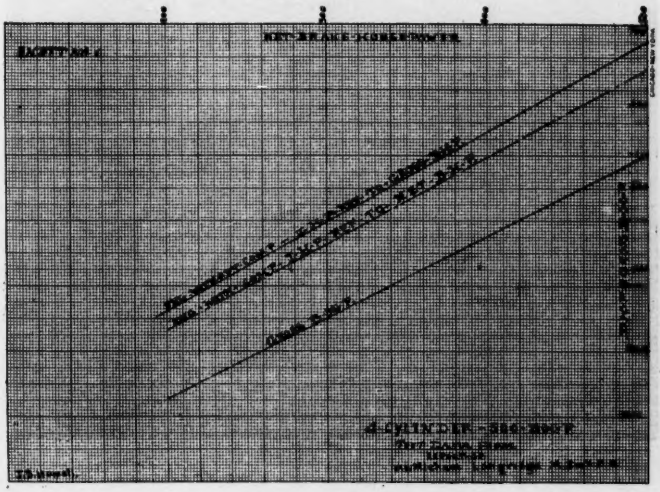
Revolutions per minute	250
Total indicated horsepower	259.52
Mechanical efficiency, assumed from curve sheet No. 304, per cent	77.3
Total brake horsepower, mean	200.93
indicated horsepower, hours	1,557.12
brake horsepower, hours	1,205.58
fuel consumed, 6 hours	485.75

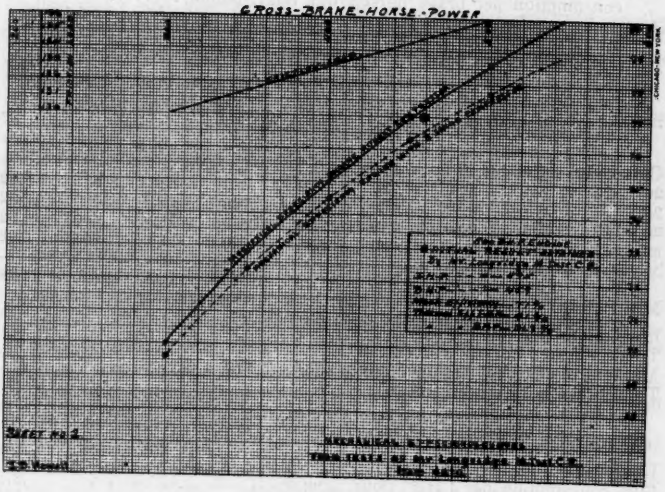
Heat value fuel per pound, B.T.U	19,649
Fuel consumption per indicated horsepower hour, pound	.3119
consumption per brake horsepower hour, pound	.4029
Heat units supplied per I.H.P. hour	6,129.00
units supplied per B.H.P. hour	7,916.59
Thermal efficiency on basis I.H.P., per cent	41.5
B.H.P., per cent	32.14

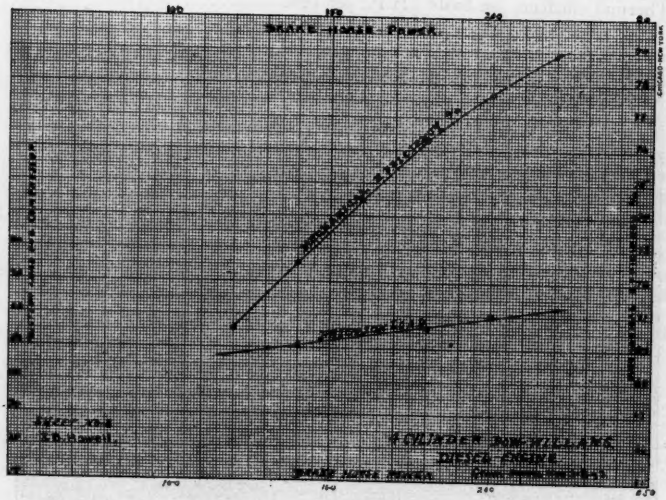
ENGINE No. 2.—THREE-QUARTER TRIAL, 2 HOURS, 3:30 P. M. TO 5:30 P. M., OCTOBER 12. 1914.

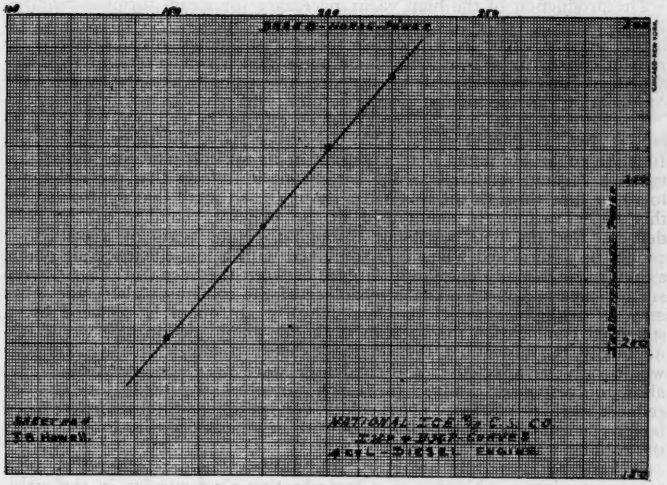
Cyls.	Cyls.	Cyl. No. 1.		Cyl. No. 2.		Cyl. No. 3.		Cyl. No. 4.	
26	25	.540	2.82	.720	2.82	.680	2.82	.635	2.82
28	27	.570	2.82	.700	2.82	.730	2.84	.660	2.82
30	29	.560	2.66	.710	2.80	.675	2.82	.660	2.82
32	31	.560	2.82	.700	2.82	.690	2.84	.655	2.82
		2.230	11.12	2.830	11.26	2.775	11.32	2.610	11.28
M.E.P., lbs.		68.985		86.457		84.328		79.594	

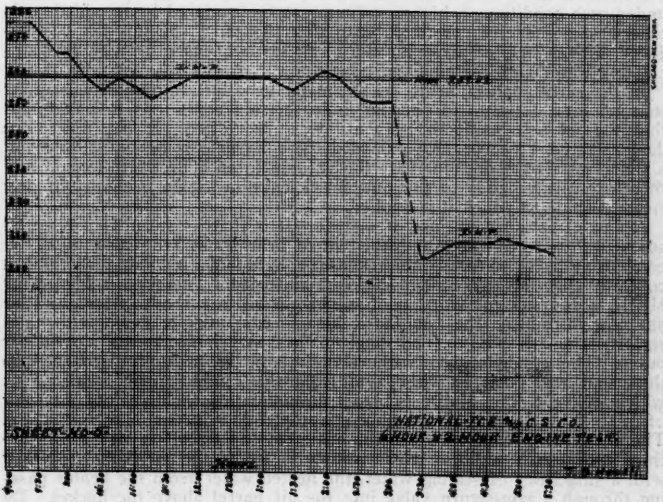
Revolutions per minute	250
Total indicated horsepower (mean)	206.69
Mechanical efficiency assumed curve sheets, 3 and 4 per cent	73.9
Total brake horsepower (mean)	152.74
I.H.P. hours	413.4
B.H.P. hours	305.48
fuel consumed, pounds	112.5
Heat value fuel per pound, B.T.U	19,649
Fuel consumption per I.H.P. hour, pound	.272
consumption per B.H.P. hours, pound	.368
Heat units supplied I.H.P. hour	5,346.5
units supplied per B.H.P. hour	7,230.8
Thermal efficiency on basis I.H.P., per cent	47.6
B.H.P., per cent	35.2




6 Cyls.-Brake-Horse-Power
Sheet No 2.
J.D. Howell.
Mechanical Efficiencies.
From tests at Mr Longridge's School C.E.
Bath 1906.


Brake-Horse-Power.
Sheet No 3.
J.D. Howell.
4 Cylinder Nov. Williams
Diesel Engine.





A HIGH-VACUUM RECIPROCATING AIR PUMP.

The production of the high vacua necessary for steam turbines requires an air pump which can withdraw from the condenser such a volume of highly aerated vapor as will enable the largest amount of tube surface to remain constantly active; but an air pump and a condenser are so interdependent that they should be regarded as one unit, as only by effective combination can the highest results be attained.

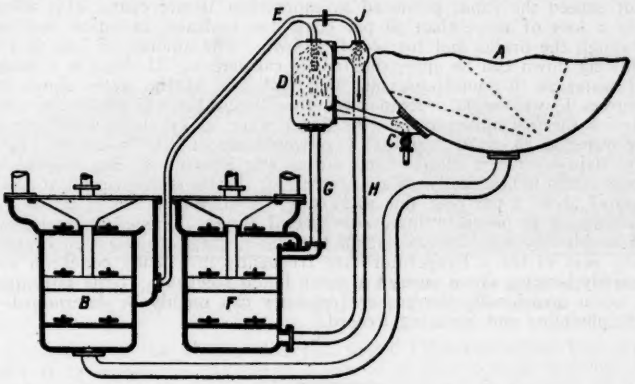
The only vacuum in a condenser which affects the economy of the turbine is that maintained in its exhaust chamber above the tubes, and as the function of an air pump is to maintain in its suction pipe the highest attainable vacuum relatively to the barometer, it follows that the resistance to vapor flow through the tube nests should be so small that approximately this latter vacuum is maintained in the exhaust chamber of the condenser. But the true resistance through the tube nests of a condenser cannot be ascertained when it is combined with a low-efficiency air pump, as under such conditions the difference between the vacua in the air-pump suction pipe and in the exhaust chamber of the condenser above the tubes may be negligible, but if the low-efficiency air pump is replaced by a steam-jet combination the vacuum in the air-pump suction pipe would undoubtedly be raised, but that in the exhaust chamber of the condenser would only be affected if the condenser were of a design which would allow of response. Failure to respond involves the triple loss of (*a*) reduced turbine efficiency, (*b*) colder condensate and therefore reduced boiler efficiency, (*c*) wasteful expenditure of pumping power in circulating the cooling water.

It has been generally accepted hitherto that the practical utility of a steam jet when combined with a reciprocating air pump lay in the maintenance of the normal vacuum when there was excessive air leakage into the system, this being secured by increasing the pressure of the jet. Whilst this is, of course, true, yet the technical value of a steam jet is at a maximum under the conditions of a practically airtight plant, because under such conditions a higher vacuum can be produced by its aid than is otherwise possible, a corollary being that the same vacuum can be produced with a smaller air pump or a smaller condenser or with less circulating water and less pumping power.

In the early application of the steam jet very little attention was given to condenser design, and because under certain conditions it was found that the jet was ineffective, its use was discredited. It has now been demonstrated, however, that provided the condenser is of suitable design, a steam jet always does increase the vacuum to an appreciable extent, and therefore always adds to the power efficiency or steam economy of any steam turbine to which it is applied.

A first essential in the use of a steam jet is that its steam is condensed amongst the feed water and the entire heat conserved; also, that the condensing is by direct contact and not by surface contact, whereby a constant efficiency of condensing is maintained. This was achieved by Mr. D. B Morison, of Hartlepool in 1907, in his kinetic-jet system, and he has now introduced the same basic idea in combining a steam jet with a reciprocating air pump. The diagrammatic sketch represents a twin air pump. The condensate is withdrawn by one barrel and discharged in the usual way. Air is withdrawn from the condenser by a steam jet which delivers into a direct-contact heater into which such a quantity of feed water from the feed tank is sprayed as will condense the steam. The air which is compressed in the heater by the steam jet into from one-third to one-half of its original volume is led to the air barrel together with a sufficiency of sealing water, the heated water from the heater passing through a non-return valve into the air barrel above the bucket. By this arrangement the technical value of the steam jet is fully realized, the

entire heat in the steam from the jet and also in the vapor withdrawn from the condenser is conserved, the size of pump for a given air duty is reduced by nearly one-half, and a minimum power is required for driving the pumps. These pumps are being used for marine geared turbines on the lines shown in the diagram, but for large land plants the condensate may be withdrawn by a small turbine-driven centrifugal, the exhaust from the turbine being utilized in the steam jet, the reciprocating air pumps being driven at a moderately high speed and at a very small expenditure of power.



HIGH VACUUM RECIPROCATING AIR PUMP.

A. Air concentrating Contraflo main condenser.
B. Barrel taking condensate from condenser.
C. Steam jet air ejector withdrawing air from condenser A and discharging into heater D.
D. Direct contact heater, into which condensate is sprayed and condenses the steam from the jet.
E. Condensate from hot well or from feed tank for condensing steam from jet in heater D.
F. Air barrel.
G. Heated water from heater D led into air barrel F between bucket and head valves.
H. Air from heater D led into air barrel F.
J. Water from hot well or from feed tank for cooling air from heater D and for sealing air barrel F.

The flexibility of the system is very great, as in the event of an abnormal leakage of air, all that is necessary in order to prevent a fall in vacuum is to supply a little more steam to the air ejector, thus preventing the mechanism from being distressed, and enabling the pump to run at such a speed as will minimize the attention required and reduce the wear and tear to almost negligible amount. As the steam for the air ejector is at low pressure, it can be taken from a closed exhaust system; in all cases, however, the steam performs the double function of withdrawing the air from the condenser, and then heating the feed water, so that neglecting radiation the thermal efficiency of the system is unity.—"The Engineer."

EVAPORATOR DESIGN.

A great deal of steam is wasted in most evaporators as fitted on board ship. As the conversion of the heat of the primary steam into vapor is a simple matter the amount of steam can easily be calculated, and if the consumption is much in excess of what it should be it will be at once indicated that something is wrong. In a single-effect evaporator the steam admitted should not greatly exceed the amount of water evaporated. When a feed heater is employed the steam used should not exceed the vapor produced by more than 10 per cent. This allows for a loss of more than 10 per cent. due to leaks, radiation and loss through the drains and for blowing down. The amount of heat lost in blowing down can be approximated by calculation. If there is 1 pound of water at 10 pounds pressure the total heat of the water above 200 degrees F. will be 987. Evaporated four times this will amount to 3,948 British thermal units. In blowing down, water at 240 degrees is replaced by water at 60 or 70 degrees. This would account for a loss of nearly 200 British thermal units if no steam was blown out, but in practice some steam is practically always blown out. There is thus an unavoidable loss of about 5 per cent. due to blowing down, which loss in actual circumstances is probably increased several times. Waste of steam can be avoided by not blowing out all the water, but little attention is, as a rule, paid to this. Evaporators are frequently in a leaky condition and possibly blowing down once in a watch is too frequent. If the saturation is taken occasionally the proper frequency can readily be determined.—"Shipbuilding and Shipping Record."

WIRELESS TRANSMISSION.

The use of sustained or undamped waves in wireless transmission has long been recognized to offer a large number of important advantages, but the generation of these waves has always been a source of difficulty. To produce an alternator of any considerable capacity which will directly generate voltages with a frequency of around 50,000 cycles is an extremely difficult proposition due to obvious mechanical and electrical difficulties.

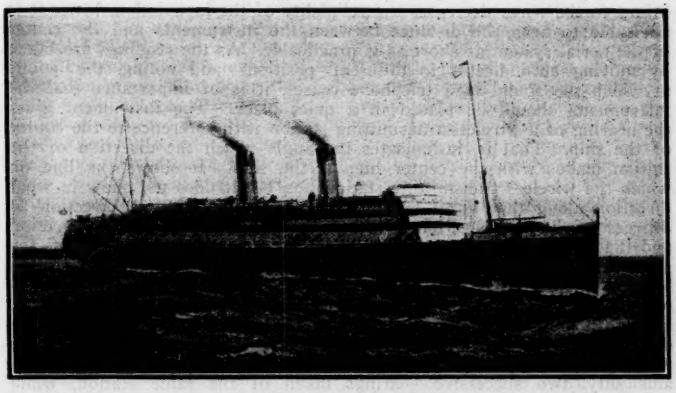
A great many of these limitations have been overcome in the Goldschmidt "reflection" alternator, such as is now operating in the transatlantic radio station at Tuckerton, N. J.

The fundamental frequency of this alternator is about 10,000 cycles, but by a ingenious system of reflection and resonance between the two windings, the output is delivered at a frequency of 40,000 cycles. The machine is of German construction, and especially rigid in design. The rotor of the alternator is driven by a 250-H.P. D. C. motor, and weighs about five tons. The speed is about 4,000 r.p.m. and the air gap is less than 1 mm. At the normal output of 110 kw., the aerial current is approximately 135 ampères, but it is claimed that the machine is capable of generating as much as 200 kw.

The receiving apparatus is ingenious in that the tone heard in the receiver is the difference tone between the transmitted frequency of 40,000 cycles and a mechanically produced frequency of about 39,500 cycles, thus giving a 500-cycle tone in the receiver. It is claimed that this system eliminates largely the interference from both static electricity and other stations.—"Sibley Journal of Engineering."

THE WIRELESS DIRECTION FINDER.

MARCONI–BELLINI–TOSI SYSTEM.



R.M.S. "ROYAL GEORGE," WHICH HAS BEEN RECENTLY EQUIPPED WITH THE MARCONI–BELLINI–TOSI WIRELESS DIRECTION FINDER.

The object of the wireless direction finder (Marconi-Bellini-Tosi system) is to enable the navigating officer of a ship to take bearings of wireless telegraph stations, with a view to finding the position of his ship or avoiding collisions with other ships. It is not claimed that bearings taken with this instrument exceed, or even equal in accuracy, those taken with an accurate optical instrument under good conditions. But it is claimed that reliable bearings may be taken with it when, owing to bad weather or other causes, direct bearings cannot be taken. Under reasonably good conditions bearings may be taken within two or three degrees, and under the worst conditions within five degrees. The accuracy of the results obtained depends almost entirely on the care with which the observations are taken, as the error due to the instrument itself does not exceed one degree. Deviation, owing to the iron work of the ship, is practically non-existent, unless the conditions are quite exceptionally unfavorable, and if it exists, is a constant factor which can be allowed for. It is not necessary to swing the ship in order to take bearings. The range of the installation is from about 5 to 50 miles or more, depending on the power of the wireless station from which signals are being received, and in the case of small ships, on the size of aerial that can be put up. It is designed to receive signals from all ordinary shore stations and ships. The direction finder requires aerial wires which are distinct from those used for the main wireless installation of the ship. The aerial system required consists essentially of two loops of equal size, suspended vertically and crossing each other at right angles. The loops ordinarily take the form of triangles of wire suspended by their apices through insulators from a triatic or other fore-and-aft stay, or from a sprit, gaff, or bracket on one of the masts. Their horizontal base wires cross the ship at the angle of 45 degrees on either side of its center line and at right angles to each other, the two bottom corners of each triangle being ordinarily made fast through insulators to stanchions at the side of the ship. Connecting wires are taken to the instruments from the centers of the horizontal base wires of the tri-

angular aerials, which are split by an insulator at their point of intersection. The range of the installation suffers to some extent if these connecting wires are very long, in addition to which the possibility of injury to the wires decreases the reliability of the installation, hence it is advisable to keep the distance between the instruments and the center of the aerial system as short as is practicable. As the readings are taken by moving an indicator to different positions and noting the points at which the sound in a telephone ceases, it is of importance that the instruments should be placed in a quiet place. The instrument gives the bearing of a wireless transmitting station with reference to the course of the ship. That is, it indicates the angle which the direction of the station makes with the center line of the ship. It shows the line on which the wireless transmitting station lies, but it does not show in what direction along that line. For instance, it may indicate a direction 20 degrees off the port bow, but it does not distinguish between this direction and that which is diametrically opposite to it, namely, 20 degrees off the starboard quarter. To use geometrical language, it shows the direction but not the sense. There will, however, seldom be any doubt as to whether the ship is approaching or receding from a land station, and, indeed, in most cases, there is only one possible way of interpreting the direction of the instrument, as by the reverse interpretation the ship would be found to be somewhere inland. If, however, there is any ambiguity, two successive bearings taken of the same station, while keeping the ship on a fixed course, will place the matter beyond doubt, and will at the same time give the ship's distance from the station by the method ordinarily in use for that purpose. In the same way the ship's position may be found by taking simultaneous bearings of two fixed stations. An obvious application of the direction finder is to find out whether the ship is on a course which will take it inside or outside a lightship or isolated lighthouse. A few signals from the lightship or lighthouse will settle the question as certainly as if the light were visible. Similarly, when making a harbor, a few signals from a station in the harbor will show immediately if the ship has drifted to one side of the entrance. When trying to locate another ship while going slow in a fog, the indication of the direction finder would show by a steadily-increasing strength of signal if the other ship were approaching, but might leave a doubt as to whether it was approaching on the port bow or overhauling on the starboard quarter; but a wireless query as to her course, addresssed to the other ship, would remove the doubt at once. The instruments consist of two separate boxes and a pair of telephones. The receiving apparatus differs very little from that in use for wireless telegraphy. A small testing instrument is provided for the purposes of adjusting the instruments and detecting any defects in the installation which might cause a wrong direction to be given. It consists of a miniature transmitter, which can be made to give signals representing those ordinarily received from outside stations. It is contained in a box on which is mounted a switch, by means of which the testing instrument can be made to give signals on either of the two waves which are ordinarily employed by ship and shore stations.

The following is a technical description of the wireless finding installation: It consists electrically of two main parts, the aerial circuits and the detecting circuits. The aerial system consists of two closed oscillatory circuits which are insulated from each other throughout and also from earth. Each of these oscillatory circuits consists of an aerial loop, in series with which are inserted a coil of wire and a condenser; the condenser being inserted in the middle of the coil of wire for symmetry. The two aerial loops, which are of equal size, are suspended in vertical planes crossing each other at right angles. The two coils of wire are also of equal size and also cross each other at right angles in vertical planes. They

are contained in a box together with their respective condensers, which are made variable for the purpose of tuning the aerial circuit to various waves. One handle varies the two condensers simultaneously. Inside the crossed coils a third coil, called the exploring coil, is mounted on a vertical spindle, by means of which it can be set at various angles with reference to the fixed coils. The detecting system consists of a pair of telephones and a crystal of carborundum, in series with a potentiometer and battery which are required to bring the carborundum into a sensitive condition. It is contained in a separate box, and is connected by wires to the exploring coil, which picks up the signals from the aerial circuits and hands them on to the detector, where they are rendered audible in the telephone. Each aerial loop is a directional aerial which receives best when its plane is in the direction of the sending station. If its plane is at right angles to the direction from which the signals are coming it receives nothing. In intermediate positions it receives signals, the induced current due to which varies as the cosine of the angle between the plane of the aerial loop and the direction of the sending station. Except in the case when one of the aerials is in a plane exactly at right angles to the direction from which signals are coming, currents are induced in both the aerials, their relative strength depending on the direction of the sending station with reference to the planes of the two aerial loops. These currents pass through the corresponding crossed coils in the direction-finding instrument, and produce in the space enclosed by them two magnetic fields at right angles to each other. The two fields, whose relative strength depends on the relative strength of the currents induced in two aerials, combine to form a resultant field at right angles to the direction from which signals are coming. The exploring coil will consequently receive the strongest signals when its plane is at right angles to that of the resultant field, or in other words, when its plane is in the direction from which signals are coming. A pointer attached to the spindle on which the exploring coil is mounted indicates the position of the latter, and consequently the direction of the sending station. In the above it has been assumed that the crossed coils are in the same planes as the crossed aerials. If the instrument is moved from this position the positions on the scale which represent the crossed aerials remain the same, so the pointer indicates correctly with reference to them.

The system is supplied by Marconi's Wireless Telegraph Company, Ltd., Marconi House, Strand, London, W.C. Its practicability and usefulness have been exhaustively demonstrated on the R.M.S. *Royal George* and *Eskimo*.—"The Steamship."

SEARCHLIGHTS.

By C. S. McDowell.

ABSTRACT OF PAPER.

Searchlights have remained practically the same for the past 25 years, although there is great necessity of an improved searchlight on account of the increased range of torpedoes and increased speed of torpedo boats.

The constituent parts of a searchlight are given in the paper and some of the essentials and desirable features of the various parts are shown. Methods of testing searchlight mirrors are given, with illustrative figures.

The results of tests conducted on Navy standard 36-inch and 60-inch searchlights and Beck 44-inch searchlights show the latter type to be much more efficient in illuminating distant objects. Relative results are shown in the figures.

Searchlights were first used during the Civil War in a very crude state; these first searchlights were fitted with metal mirrors. Later, Fresnel lenses were used to concentrate the beam. In 1876 the Mangin type of mirror was first brought out and in 1886 Schuckert, in Nuremburg, succeeded in producing a glass parabolic mirror ground to mathematical accuracy. Practically no changes have been made since that time to increase the efficiency of the searchlight; some mechanical improvements have been made, and methods of manufacture of carbons perfected, but practically the ordinary searchlight of today is the same as that of 25 years ago.

In view of the increasing speed of torpedo-boat destroyers and the increased range of torpedoes, it is very important that the searchlight, one of the principal means of defence against night attack, should be improved if possible. There has lately been developed by Mr. Heinrich Beck of Germany, a new type of searchlight much more efficient than those now in use, which is described a little later in this paper.

In considering the question of searchlights and their relative efficiencies it becomes natural to consider them as made up of the following constituent parts:

1. Searchlight, drum, pedestal, system of control in azimuth and in elevation, shutters and other purely mechanical details.
2. Rheostats.
3. Searchlight mirror.
4. Lamp mechanism.
5. Searchlight arc.

One type of searchlight may show increased efficiency over another because some of these parts have been worked out to give the very best results, but a searchlight to give the very best results must have all these details worked out separately and then joined together in the proper relation to give the maximum efficiencies.

Searchlight drum and other mechanical details are questions of design which affect the efficiency of the light very little. They should be worked out carefully, however, so that the searchlight is properly balanced, may be easily trained in azimuth and elevation from a distant control station or at the light itself. The drum should be so made that air currents cannot be set up inside, thereby causing flickering of the arc; ventilation should be sufficient so that light may be kept on at full intensity with shutter closed, or other means adopted for keeping the light burning at lower intensities with shutter closed and bringing it to full intensity instantly upon opening of shutter. It is also considered advantageous to have a permanent ammeter and voltmeter mounted on the searchlight drum, or a connection on it so that portable instruments can be connected. A ground-glass finder which shows the position of the arc, the arc length, and the variations of the positive crater from the focus of the mirror is considered an essential in a properly designed searchlight. The mirror should be so secured that it may be readily removed and the mirror and front door strips should be mounted in such a manner as to eliminate shock and breakage.

The rheostat used in connection with searchlights consists of two parts: a fixed and a variable resistance. A certain amount of fixed resistance is necessary to overcome the natural unstability of a carbon arc, and its value must be at least sufficient to give a voltage drop in the resistance equal to one-half the arc stream voltage. The variable resistance is necessary in order to obtain the proper arc voltages for various carbons and various lengths of line. The resistance elements must be of sufficient area to carry the maximum currents used without undue heating of any parts and of such material that the resistance does not change excessively with temperature changes. The steps should be not greater than one volt each.

The efficiency of a searchlight mirror depends upon its trueness to parabolic form, its trueness of surface grinding, the color and structure of the

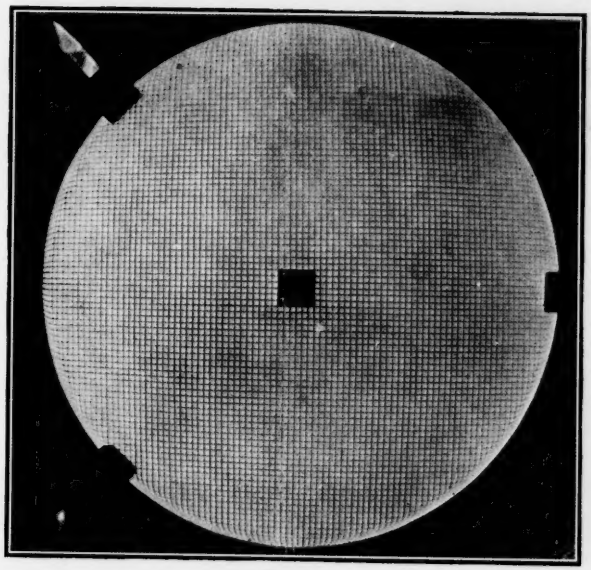


FIG. 1 [MCDOWELL]

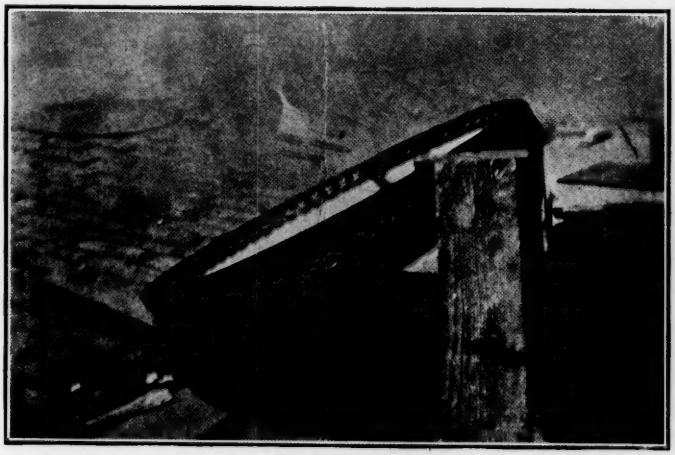


FIG. 2 [MCDOWELL]

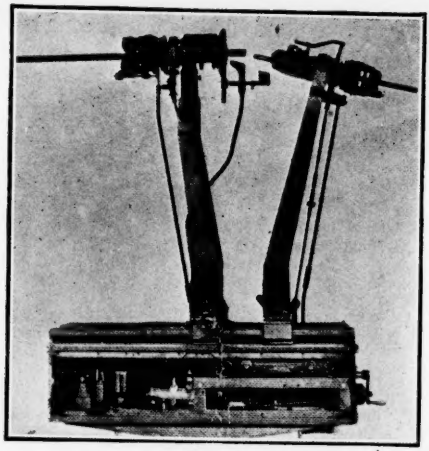


FIG. 4 [MCDOWELL]

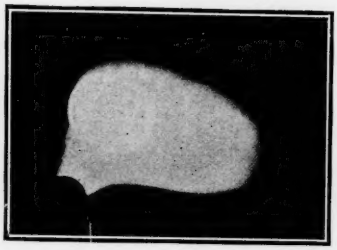


FIG. 7 [MCDOWELL]

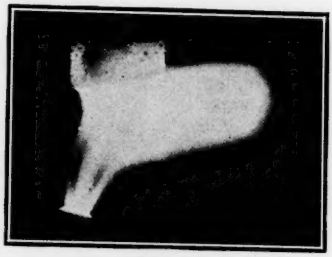


FIG. 8 [MCDOWELL]

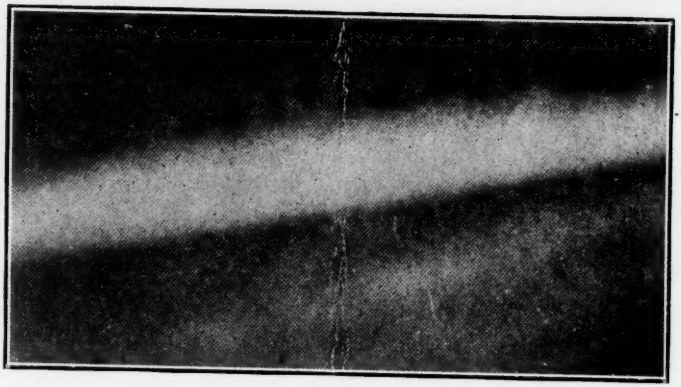
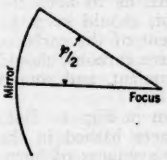


FIG. 9 [MCDOWELL]

glass, and the thickness of the glass. The losses in searchlight mirrors are due to stray rays outside of the conical beam and to absorption in the mirror. The intensity of illumination on a distant object, provided equal amounts of light fall on the mirror, is dependent on the efficiency of the mirror and the angle of dispersion (that is, at a distance, the area of the illuminated plane normal to beam).

The relation between the focal length and diameter of the mirror should be such that the effective angle φ should include the majority of light given off by the arc. By increasing the focal length, the diameter of mirror remaining constant, the ratio of the light falling on the mirror to the total given out by the arc is decreased but also the angle of dispersion is decreased, therefore, the correct focal length is that which, changed in either direction, decreases the foot-candle illumination on a distant object. If we increase the diameter of the mirror at the same time as the focal length is increased, the angle φ can be maintained constant and at the same time the dispersion decreased, thus giving greater intensity of illumination on a distant object. On board ship, however, the size of the searchlight, and thus the diameter of the mirror, is limited. A greater focal length is also of advantage in that it takes the arc farther from the mirror and thus decreases the chances of breakage of the mirror due to the heat of the arc.



In determining the efficiencies of searchlight mirrors, various tests are carried out:

(*a*) *The Line or Screen Test.*—If we imagine a section taken through the center of the mirror, a curve is obtained whose curvature should vary in a regular manner from the center towards the edge, but the curve will take a wavy form instead if the surface has not been accurately ground.

The mirror is erected opposite a screen on which are painted two systems of parallel straight lines at right angles to one another. The image of these lines is photographed by a camera placed back of the hole in the center of the screen. If both surfaces of the mirror are properly ground the lines in the photograph should be regular but not necessarily straight nor parallel. This test does not show if the mirror is parabolic or not.

An illustration of a mirror showing this test is given in Fig. 1.

(*b*) *The Sun or Zone Test.*—A perfect mirror should reflect rays from a point of light situated at its focus, in parallel straight lines. It must, therefore, also have the property of bringing a parallel beam of light, as from the sun, to a focus in a single point. This as made, consists in placing the mirrors in a plane perpendicular to the sun's rays and photographing the reflected focal point, brought out in contrast by blowing smoke on it.

An illustration of this test is shown in Fig. 2.

(*c*) *Beam Photometric Tests.*—It is considered that the most reliable test of mirrors is to actually mount them in a searchlight, place a constant source of light in the focus, and at a standard distance measure the actual foot-candles of illumination throughout the entire beam. The focal point of a mirror to be tested is first accurately obtained (our method being to place two mirrors exactly parallel with each other about 30 feet apart and place a concentrated filament lamp approximately at the focal point of the second and measure accurately the focal length of the first); the mirror under test is then mounted in a searchlight frame held in a fixed position, a concentrated filament lamp placed accurately in the focus (a 50-watt lamp is used) and at a standard distance measure the foot-candles by a portable photometer. These foot-candle readings are usually obtained every four inches across the beam on two lines perpendicular to each other and passing through the center. For the larger size mirrors

200 feet has been taken as the standard distance. Curves obtained in this test are shown in Fig. 3.

By calculating the amount of light flux falling on the mirror and that received on the distant object the losses in the mirror may be found and the coefficient of reflection obtained.

In a number of cases mirrors which showed nearly perfect grinding and sharp focal point, as determined by the first two tests, were found on this third test to reflect less light than other mirrors which had shown much poorer results on the screen and zone tests.

The lamp mechanism of a searchlight should be such as to keep the crater of the positive carbon at the focus of the mirror, should keep the arc length that which is desired, should carry the current of the carbons, should contain mechanism for rotating at least the positive carbons, should be sufficiently rigid to keep the carbons in proper alignment, and should require little care and adjustment.

An illustration of the Beck lamp mechanism is shown in Fig. 4. Both carbons are rotated for the purpose of keeping surfaces bathed in the inert gas and to keep the arc central and thus promote evenness of burning. The positive holder is fixed, the carbon being fed through it at such a rate that the crater is always maintained at the focus of the mirror; the rate of feed is controlled automatically, a small mirror being placed

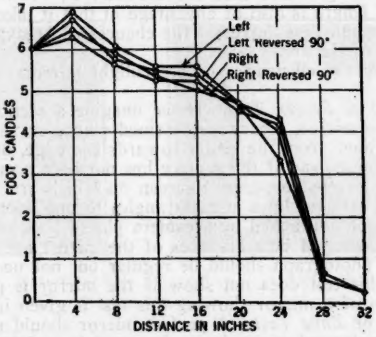


FIG. 3.—CONCENTRATED FILAMENT LAMP TEST OF THE NAVY STANDARD 36-INCH SEARCHLIGHT MIRROR TAKEN IN FOOT-CANDLES AT A DISTANCE OF 200 FEET—50-WATT, 6-VOLT, CONCENTRATED FILAMENT LAMP USED.

in the drum which, when the carbon feeds too slowly, reflects a small beam on a thermocouple, and closes a relay circuit which by means of a solenoid quickens the feed. When the carbon is back in focus the small beam of light is off the thermocouple and the feed is slowed down. In addition, the feed may be controlled by hand. The negative carbon feeds through the negative holder in a similar manner, except that the control is by hand. The negative holder is also fixed except when striking the arc, when it is moved up by a striking motor.

During tests recently conducted on searchlights the Beck lamp mechanism functioned very satisfactorily; variation of the crater of the positive carbon from the focus was about 1 mm. (hardly noticeable) and the arc length was kept practically constant. No trouble in maintaining the arc was experienced while rotating both carbons, the crater of the positive carbon remained even and there was no noticeable hissing and jumping of the arc. On the other hand, while the standard motor-controlled lamp

mechanism functioned successfully, maintaining practically a constant voltage, the arc length did not remain constant and the positive crater did not remain at the focus, due to the impracticability of constructing positive and negative carbons which will be consumed at a certain given ratio. Also the positive crater tended to wander over the surface of the positive carbon with the result that one side would project and the other recede, causing a hissing arc and making it necessary, in order to obtain any consistent results, to shut off the light and turn the positive carbon by hand about every 15 or 20 minutes.

We now come to the arc, probably the most important part of the searchlight and also the one least understood. There have been numerous treatises written on the arc, but it has been always discussed from the general illuminating side and without much consideration of its uses for searchlights. Paragraphs have been written in some illuminating treatises on the searchlight arc, but it has in general been given scant attention. This is probably more or less natural, for the authors of these books were not especially interested in searchlights, and, as a rule, had had very little experience with the subject.

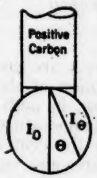
The desired searchlight arc should excel in the following particulars:

1. Small positive carbons with high current densities and thus high crater temperature throughout crater area, which gives high intrinsic brilliancy. Intrinsic brilliancy is the luminous intensity per unit area.
2. Small negative carbons.
3. Long arc length, that is, distance between positive crater and negative point.
4. Uniform mixture of carbon so as to help the evenness of burning.

The Beck searchlight may be considered as being especially designed to meet the above requirements, and therein lies its marked superiority over the searchlights now in use.

In a searchlight the angle of dispersion is directly dependent on the diameter of the source of illumination, provided the focal length is constant, and if the diameter of the source can be decreased one-half while the candle power remains constant, the intensity of light on the target would be quadrupled. Actually in the Beck light, the positive carbon is reduced one-half and at the same time the candle-power is increased so that greater efficiencies are obtained.

To illustrate the effect of arc length on candlepower it may be stated that with a circular plane radiator (the crater of the positive carbon approximates such a radiator) the maximum candlepower is obtained on the vertical axis of the radiator as shown by the sketch. Here we have I_0 = maximum intensity, and $I_\theta = I_0 \cos\theta$. Thus the smaller the angle the greater the maximum intensity of light falling on the mirror. With positive and negative carbons of a fixed diameter the angle θ depends upon the arc length, being the angle of partial shadow on the mirror projected by the negative carbon cutting off through this angle the light rays emitted by the positive carbon. This may be more clearly expressed by the formulas



$I_\theta = I_0\, q \tan\theta$ where I_0 = the normal intensity as before.
I_θ = the intensity at any angle θ from the normal, and

$q = \frac{\pi r^2 - S}{\pi r^2}$, where r = radius of positive carbon, and

S = the area of overlap of the negative on the positive for the angle θ.

The light intensity is reduced by the shadow of the negative carbon only for those angles of θ which are smaller than $\tan\theta = \frac{r + r_1}{l}$, where

r = radius of positive carbon,
r_1 = radius of negative carbon,
l = arc length.

Thus it is seen that to decrease the angle of shadow it is necessary to increase arc length or decrease the diameter of negative carbon. The arc length is restricted to the stability point of burning.

In Fig. 5 is shown by curve the increase of candle power with increase of arc length; the candle powers are taken at 40 degrees from the normal to arc surface and are approximately the maximum.

The arc length of the Beck lamp is maintained constant at about 7/8 inch as compared to about 5/8 inch obtained at 60 volts in the standard 36-inch lamp.

Fig. 6 shows the variation of arc voltage with arc length as determined on a set of ordinary 36-inch carbons with constant current of 110 ampères.

It is, of course, well known that carbon is the most refractory of all known materials, boiling at about 4,000 degrees C., but it unfortunately commences to evaporate at a much lower temperature (about 1,800 degrees C.), so that in an ordinary arc very little of the total area of the end of the positive carbon is at the melting temperature, a small wandering spot being the real efficient part of the carbon, and the rest of the end of the carbon is consumed at a much lower temperature, giving off less intense rays and a longer wave length. This may be readily seen in comparison of the Beck and ordinary arc by the color of the arc.

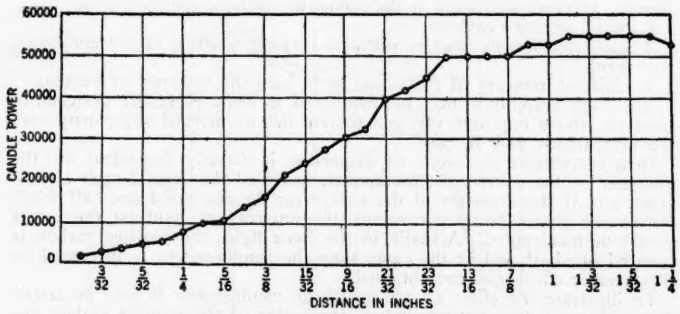


FIG. 5.—CANDLE POWER–ARC LENGTH CURVE TAKEN AT A POINT 40 DEGREES FROM NORMAL TO THE ARC SURFACE—NAVY STANDARD CARBONS—CURRENT NORMAL 110 AMPERES.

In the Beck arc the ends of the positive and negative carbons are enveloped in the hydrocarbon vapors which prevents the consumption of the carbons at a lower temperature, by keeping oxygen from them, in addition it cools the outer shell of the carbons, the gas being at a temperature of about 1,000 degrees C., and thus concentrates the current in the center of the carbons; thus a current density greater than 0.75 ampères per sq. mm. is obtained, and the total crater of the positive carbon reaches a very high temperature. The current is brought to both carbons near the ends by roller contacts, so the only part having this high current density is the part protected by the indifferent gas. The positive carbon is cored with a rare earth with a melting point at about 3,500 degrees C. The positive develops a deep crater, about 12 mm. deep, filled with incandescent gas. The sides of this crater reflect the light radiation to the focus of this crater, and in addition, the light from the negative is reflected, so it is believed nearly true black body radiation is obtained; and by adjusting the focus of the crater to focal point of the mirror the high peak in the luminosity curve of the beam is thus accounted for.

The area of the Beck positive carbon is 201 sq. mm., the area of the ordinary 36-inch light positive carbon is 805 sq. mm. In the Beck light the maximum intrinsic brilliancy is greater than 438 c.p. per sq. mm. The intrinsic brilliancy of an ordinary carbon arc varies from 120 c.p. per sq. mm. to 160 c.p. per sq. mm.

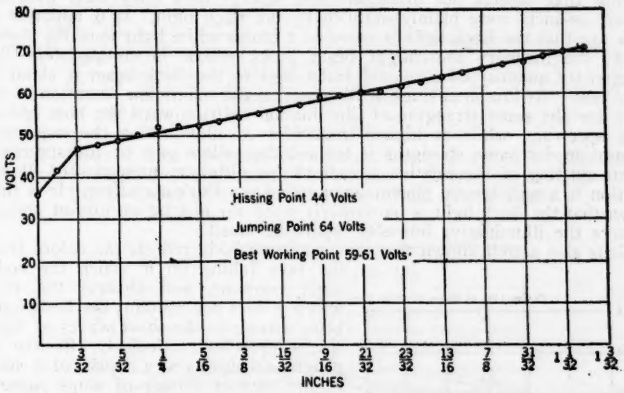


FIG. 6.—ARC VOLTAGE-ARC LENGTH CURVE—NAVY STANDARD CARBONS USED —LINE CURRENT CONSTANT AT 110 AMPERES.

In addition to the black body radiation obtained from the crater there is evidently a large amount of light radiated from the incandescent gas in the crater, of a selective nature. It would probably at first be thought that this gas should follow Kirchhoff's laws and absorb the lines which they naturally radiated, giving the Fraunhofer lines seen in the sun's spectrum; but in this case the incandescent gas is at a higher temperature than the crater and the spectrum shows positive lines apparently superimposed on the regular temperature radiation.

It is noticed that taking the Beck carbons and starting at a low current density a luminous arc stream as of a typical white flame arc is obtained, the anode being convex. As the current density is increased the anode becomes concave and the anode stream disappears, apparently being confined to the crater of the positive carbon, leaving only the lower temperature and less luminous cathode stream. The temperature of the incandescent gas within the positive crater is estimated to be between 5,000 and 5,500 degrees C. Two views of the Beck carbons burning with normal current densities are shown in the illustrations, Figs. 7 and 8.

For the luminous power J_1, which reaches the eye of the observer, we have the following equation:

$$J_1 = \frac{J}{L^4}(1 - P)^{21} K.$$

J = Luminous power of the searchlight.
L = Distance of illuminated object (under the assumption that the observer is near the searchlight).
P = Absorption by the atmosphere.
K = The coefficient of reflection of the illuminated object.

Thus if we assume that a searchlight of certain illuminating capacity makes it possible to easily distinguish an object at 4,000 meters, then a searchlight of four times the illuminating capacity will carry 5,300 meters,

assuming that the absorption of the atmosphere is 10 per cent. per kilometer and that the object is equally well distinguished in each case.

It is very hard to compare two searchlights by the eye, but during the test conducted, both searchlights were lighted (Beck and Navy 36-inch) and first one and then the other was turned on the same object with the result that objects not distinguishable, except in a hazy way, with the Navy 36-inch, were plainly outlined by the Beck light. It is apparent to the eye that the Beck light is more of a bluish white light than the standard; the ordinary searchlight beam looks yellow in comparison. The aggregate quantity of blue and violet rays in the Beck beam is about 23 per cent. At low intensities of illumination the maximum sensation to the eye for the same strengths of illumination shifts toward the blue end of the spectrum, while at higher intensities of illumination the maximum sensation for same strengths is toward the yellow part of the spectrum. This shifting of the relative sensations for different intensities of illumination is a well known phenomenon called the Purkinje effect. It is thus seen that the Beck light is particularly good for picking up distant objects where the illuminative intensity would be small.

It is also a well known fact that a colored body reflects the colors from the rays falling on it which the body itself contains, and absorbs the rays which it does not contain; the Beck light being strong in the short waves of light would thus be particularly effective in picking up objects of a bluish color, such as the various classes of ships painted bluish gray.

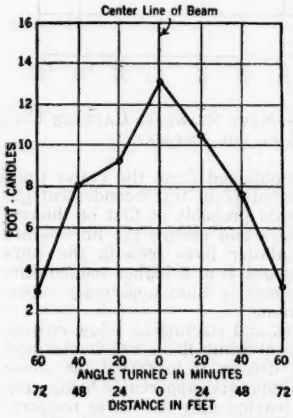


FIG. 10.—FOOT-CANDLE POWER-DISTANCE CURVE OF THE BECK 44-INCH SEARCHLIGHT TAKEN AT A DISTANCE OF 2,850 FEET —LAMP BURNING NORMALLY.

An illustration is shown, Fig. 9, of the Beck light and of a standard 36-inch searchlight, the upper beam being that of the Beck light and the lower of the standard light.

Comparative night illumination tests were conducted between standard 36-inch and 60-inch searchlights and the 44-inch Beck searchlight. The Beck searchlight beam was a more concentrated beam than that obtained from either the 36-inch or 60-inch beam of the standard lamp and the color of the Beck beam was a whiter one than that obtained from the Navy standard 36-inch and 60-inch searchlights. With the carbons burning in a normal condition and placed in the proper focal centers of their respective mirrors, foot-candle-power readings at intervals of 24 feet, were taken across the beam at a distance of 2,850 feet from the searchlights. Figs. 10 and 11 show the illumination across the beam of the Beck searchlight compared with the 60-inch standard searchlight. From these two curves it can be seen that the maximum illumination obtained from the Beck light is approximately 2½ times as great as that obtained from the standard 60-inch. In the Beck searchlight the beam shows a very high illumination at the center and falls off very rapidly at the edge of the beam. The other figures, 12 and 13, were obtained in comparing the Navy standard 36-inch searchlight with the Beck light. The figure containing the results of the 36-inch standard searchlight consists of five curves; the curves indicated by 1, 2 and 3, are plotted from actual results obtained;

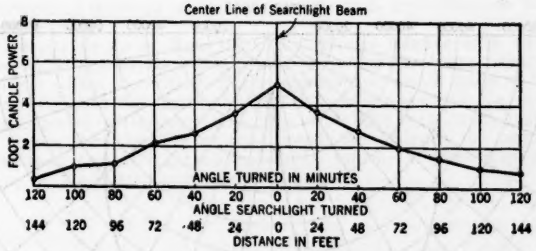

Center Line of Searchlight Beam
FOOT CANDLE POWER
8
6
4
2
ANGLE TURNED IN MINUTES
120 100 80 60 40 20 0 20 40 60 80 100 120
ANGLE SEARCHLIGHT TURNED
144 120 96 72 48 24 0 24 48 72 96 120 144
DISTANCE IN FEET

FIG. 11.—FOOT-CANDLE POWER-DISTANCE CURVE OF THE NAVY STANDARD 60-INCH SEARCHLIGHT TAKEN AT A DISTANCE OF 2,850 FEET—LAMP BURNING UNDER NORMAL CONDITIONS.

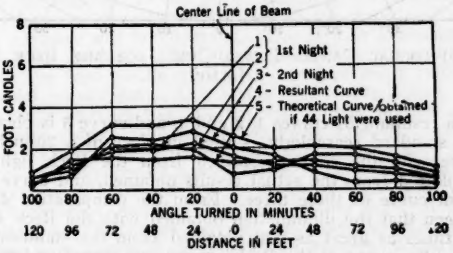


FIG. 12.—FOOT-CANDLE POWER-DISTANCE CURVE OF THE NAVY STANDARD 36-INCH SEARCHLIGHT TAKEN AT A DISTANCE OF 2,850 FEET.—LAMP BURNING UNDER NORMAL CONDITIONS.

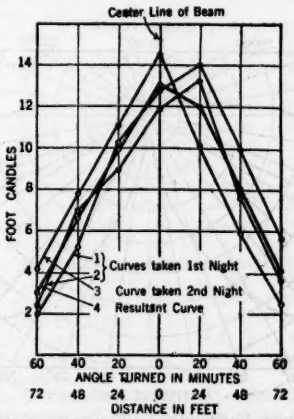


FIG. 13.—FOOT-CANDLE POWER-DISTANCE CURVE OF THE BECK 44-INCH SEARCHLIGHT TAKEN AT A DISTANCE OF 2,850 FEET—LAMP BURNING UNDER NORMAL CONDITIONS.

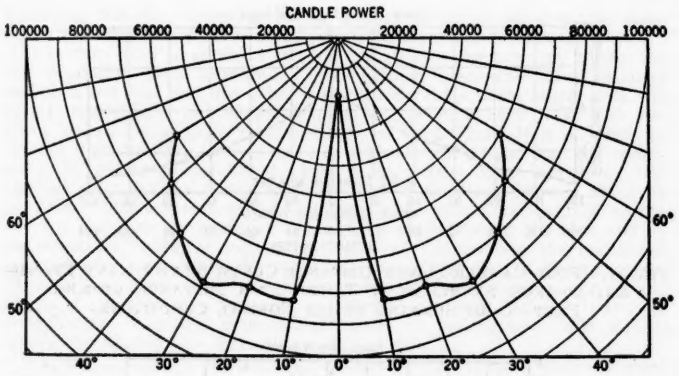


FIG. 14.—SPHERICAL CANDLE-POWER CURVE FOR THE BECK SEARCHLIGHT LAMP.

curve 4 is a resultant of curves 1, 2 and 3, and curve 5 is obtained if a 44-inch Navy standard searchlight is used in place of a 36-inch light. The other figure with the results obtained from the Beck light contains 4 curves; 3 plotted from the actual results obtained, and curve number 4 is the resultant curve of these three. From the comparative data obtained, it can be seen that the illumination obtained with the Beck searchlight is about five times as great as that obtained from the standard light. The spherical candle power of the Beck arc was measured and the results obtained are shown in Fig. 14. The maximum candle power obtained with the use of our present Navy standard carbons is 45,000 candle power, as against 88,000 candle power obtained from the Beck lamp. A zonal candle-

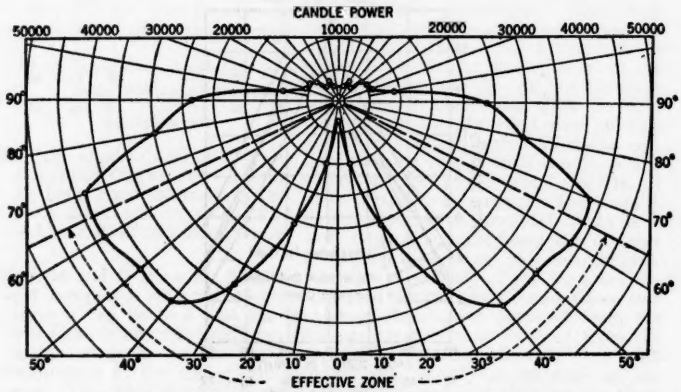


FIG. 15.—CANDLE-POWER DISTRIBUTION CURVE OF NAVY STANDARD CARBONS —LINE CURRENT 110 AMPERES—ARC VOLTAGE 60 VOLTS— ARC LENGTH CONSTANT AT 19/32 INCH.

power curve of standard 36-inch carbon arc with arc voltage at 60 volts is shown in Fig. 15.

The results shown in Figs. 10, 11 and 13, are relative only, and cannot be used to determine the zonal candle power of the beam reflected from the mirror. The absorption of the atmosphere would have to be taken into consideration to obtain the actual candle power of the beam; the results obtained in Germany with this same light were much higher than those shown here, but the relative intensities between the ordinary arc and the Beck arc were approximately the same.—"Proceedings American Institute of Electrical Engineers."

THE RESISTANCE OF THE FULL SHIP.

Experimental work on ships' models has revolutionized the forms of warships of all nations. If the performances of the modern battleships of the United States Navy be compared with the records of older ships a remarkable advance will be observed. The British Government has for many years been guided by the Haslar establishment, and the uniform excellence of the trial results of British warships bears testimony to the value of model experiments. The forms of French, Italian, Russian and German warships likewise bear the impress of experimental investigation. In the merchant service also the best is being gradually introduced, and the record-breaking propensities of the express Cunarders, the splendid performances of many cross-Channel steamers, and the economy of many of the slower cargo and passenger ships have been ensured by experimental work on ships' models. The bulk of the ships built in this and other countries are for cargo carrying only, and in this type economy in propulsion is an essential of commercial success. Experimental work has shown that great savings may be effected by a judicious selection of form. In this connection the work of Prof. Sadler of Michigan University, of Constructor D. W. Taylor of the Washington tank, and of Mr. G. S. Baker of the National Physical Laboratory, guides as to the directions in which savings may be effected.

Some very important work on full merchant-ship forms has been accomplished by Prof. Sadler, the results of which are to be found in Vols. 15, 16 and 17 of the Transactions of the American Society of Naval Architects and Marine Engineers. He has experimented with models ranging from .5 to .85 block coefficient and of normal and extreme proportions, in deep and in shallow waters. In experiments dealing with vessels of 8 beams to length and of .733 block coefficient he found that long parallel middle body and fine ends was preferable to no parallel middle body and full ends, and that the residuary resistance in the latter model was double that of the model with the fine ends at the speed proper to such a block coefficient. At this speed there was found to be a difference in total resistance of from 20 to 30 per cent. between the extreme forms. In succeeding experiments dealing with block coefficients of .653 and .855 the effect of alteration to the form of the sectional area curve was further investigated. The results of these experiments indicated that up to forms of about .8 block coefficient it is of decided advantage to have a long parallel middle body and a fine bow, but beyond that fulness round and easy bow and buttock lines are more effective in reducing resistance than having fine ends.

In Constructor D. W. Taylor's book, "The Speed and Power of Ships," the results of experiments on full ships are given amongst other valuable information. The special work to which attention is here directed is that dealing with the optimum length of parallel middle body for full

ships. As indicated in the previous note regarding Prof. Sadler's work, a diminution in resistance accompanies introduction of parallel middle body, and the results of Taylor's investigations go to show that the lengths of parallel middle body which would give the minimum of resistance are respectively 16, 27 and 35 per cent. for prismatic coefficients of .68, .74 and .80. In very full ships of just over .80 block coefficient from 40 to 50 per cent. of the vessel may be the same form as that midships.

Mr. G. S. Baker, in a paper read this year before the Institution of Naval Architects, on the resistance of merchant-ship forms, gave further light on the resistance of very full ships. The prismatic coefficients of the full models tried range from .67 to .843, which covers practically all fulnesses of cargo ships. In the fullest form tried 50 per cent. parallel middle body was adopted, which is probably just a little more than Taylor's experiments would suggest as being the optimum, but the results obtained warrant the adoption of even as much as this in the fullest vessels. One of the features of Mr. Baker's results is the influence that the run has on the resistance of full ships. A moderate fining of the prismatic curve aft brought about a reduction in resistance of 15 per cent., whilst the displacement was reduced by only 4 per cent. This finding, noticed in conjunction with a finding of Sadler that a reduction of 1.25 per cent. in displacement gave a reduction of resistance of 10 per cent., seems to indicate that it may not be advisable to go above a certain block coefficient even for slow cargo ships, as every increase in displacement over a certain coefficient means a more than proportionate increase in power. This limit seems to be reached with a block coefficient of about .78, although it is possible that considerations of effect of weather on sea performances may indicate that even that is too full for the most economical cargo ship. A deal depends on the proper distribution of displacement apart from the actual fulness of the ship, and a careful study of the work of these experimenters will repay the searcher after the form of least resistance for full cargo ships.—"Shipbuilding and Shipping Record."

LAUNCHING DATA FOR A BATTLESHIP.

By Naval Constructor John G. Tawresey, U. S. N.

ABSTRACT.

The launching of a great ship is always a matter of interest to the profession and one of anxiety to those responsible. The experience from an unbroken series of successful launches, backed by the knowledge that every condition has been investigated and every precaution taken, is not sufficient to entirely banish the thought that there may be some unusual factor for which allowance has not been made. The data for some previous vessel, especially one of corresponding dimensions and weight, are the basis of the launching arrangements adopted for a new vessel; and the great value of such data, when full and reliable, is considered sufficient reason for adding the following notes on the launching of a battleship to the valuable papers on launching already contained in the Transactions of the Society.

The launch of the *Oklahoma* was entirely successful, and the statement of data is presented as showing regular practice, not as an example of novel methods. The arrangement for distributing the pressure at the fore poppets is effective, and is presented as an alternative to the use of crushing chocks. Checking arrangements were not used. It may be worth noting that the retarding effect of rope stops, as generally used

for checking, is greater than the work done in stretching and breaking the stops.

The moving-picture method of observation was successful and is accurate. The arrangement used is fully described in the paper, also a more convenient arrangement recommended for any future observations. Attention is invited especially to the enlarged part of a curve determined photographically, and to the closeness with which the usual stop-watch observations correspond to this curve. The proof of accuracy is the agreement of the distance between stations as determined from the microscope readings from the film and the known distances apart at which they were located.

The distance the vessel ran beyond the calculated point before pivoting actually occurred is interesting. It is caused mainly by the effect of the wave on the distribution of displacement, and tends to somewhat increase the pressure on the fore poppets when the vessel lifts. The form of wave profile on the ship just before pivoting, also the very small movements just at the start of motion, are suggested as interesting parts of the launching operation for further investigation by the photographic method.

It is not suggested that moving-picture data are desirable for all launches; the curves show that stop-watch observations, carefully made, give reliable information. It is to be noted, however, that dimensions and launching weights change; practices, precautions and other launching conditions change; the kind and quality of materials that must be used change; and it is advisable that launchings be rigidly investigated from time to time and that accurate observations and records be made. Photographic methods offer advantages to that end.

LAUNCHING DATA, U. S. S. "OKLAHOMA."

Type of vessel	Battleship, First Line
Builders	New York Shipbuilding Co., Camden, N. J.
Date of launch	March 23, 1914

Principal Dimensions, Etc.

Length between perpendiculars	575 feet
Breadth on load waterline	95 feet 2½ inches
Mean draught	28 feet 6 inches
Displacement	27,500 tons
Percentage completion at time of launch	61 per cent.
Weights worked into vessel	11,765 tons
Temporary weights on board	85 tons
Men, tools, and dunnage	115 tons
Launching cradle	470 tons
Total launching weight	12,435 tons
Draught after launching, forward	13 feet 7 inches
Draught after launching, aft	16 feet 4 inches

Building Slip, Launching Ways, Cradle, Etc.

Declivity of building slip, per foot	11/16 inch
Declivity of keel blocks, per foot	11/16 inch
Length of ground ways over all	644 feet
Length of ground ways submerged	167 feet
Width of ground ways (each)	60 inches
Thickness of ground ways	16 inches
Declivity of ground ways, per foot	11/16 inch
Camber of ground ways	None

Inclination of ground ways, transverse, per foot.....⅜ inch
Spread of ground ways, center to center.....28 feet 6 inches
Material of ground ways.....Yellow pine faced with oak
Length of sliding ways over all.....473 feet
Length of sliding ways, effective.....465 feet
Thickness of sliding ways.....15 inches
Maximum width of sliding ways.....58½ inches
Effective width of sliding ways.....57 inches
Bearing area.....4,420 square feet
Material of sliding ways.....Yellow pine faced with oak
Length over which poppets distribute pivoting pressure.....23 feet
Area under poppets to take pivoting pressure.....220 square feet
Projected length of curved bearing surface under fore poppets, 21 feet 9 inches
Projected area of trunnion segment to take pivoting pressure, 208 square feet
Number of wedges, spaced 17-inch centers.....590
Wedges, oak, 9 feet by 6½ inches, tapered ½ inch per foot.
After end of sliding ways at start, up from water's edge.....6 feet
After edge of rudder at start, up from intersection of prolonged keel line and water, about.....9 feet
After perpendicular to after poppet bearing on ways.....66 feet
After perpendicular to after poppet bearing on ship.....78 feet
Forward perpendicular to forward end of sliding ways.....44 feet
Forward perpendicular to center of fore poppets.....59 feet
Means for distributing pressure at fore poppets, Rocker formed as a segment of a trunnion

Pressure, Velocity, Coefficients, Etc.

Total weight on ground ways.....12,435 tons
Initial pressure per square foot.....2.82 tons
Maximum pressure per square foot over ground way ends.....5.3 tons
Center of gravity forward of center between perpendiculars.....7.9 feet
Distance traveled to calculated pivoting.....459 feet
Distance traveled to observed pivoting.....569 feet
Distance traveled from calculated pivoting to end of ways.....181 feet
Calculated buoyancy at pivoting.....8,875 tons
Pressure on fore poppets at pivoting (neglecting buoyancy of packing).....3,090 tons
Pressure per square foot under fore poppets at pivoting.....14.05 tons
Pressure per square foot on projected area of trunnion segment at pivoting.....14.85 tons
Distance traveled to bring center of gravity over end of ways.....410 feet
Depth of water over ends of ways (actual corresponding to 5 feet 10 inches tide).....9 feet 6 inches
Least excess of calculated moment to prevent tipping.....52,200 ton-feet
Static drop of vessel where poppets leave the end of ground ways, 6 feet 4½ inches
Average velocity first 100 feet (5.8 feet per second).....3.3 knots
Maximum velocity (23.6 feet per second).....Nearly 15 knots
Ship hung 2 or 3 seconds and then started slowly without application of rams or other means.
Travel before rudder entered water, about.....25 feet
Travel to point of maximum velocity, about.....100 feet
Time to point of maximum velocity.....17.25 seconds
Travel to point of drop, fore poppet at end of ways, about.....640 feet
Time to point of drop, about.....41.6 seconds
Coefficient of starting (sticking) friction, about.....0.0575

Coefficient of friction, average first 50 feet, about.....0.026
Coefficient of friction and resistance, average first 100 feet, about....0.016
Coefficient of friction and resistance, minimum, about.....0.004
Coefficient of friction and resistance, average after 250 feet run, about 0.06

Miscellaneous.

The recorded weight at time of launch were substantially confirmed by the observed displacement.

Method of release—hydraulic triggers.

Pressure used for triggers—Started with 250 pounds per square inch and was gradually increased as blocks were removed to a maximum of 1,600 pounds per square inch just before dog shores were dropped.

Temperature on day of launch on building slip, 31 degrees F.

Lubricant on ground ways—Under fore poppets applied several weeks before launching. First a thin coat of stearine, next a 9/16-inch thick coat half tallow, half stearine.

On remainder of ground ways under sliding ways, applied two to three weeks before launching. First a thin coat of stearine, next a mixture of three parts tallow to one part stearine.

Remainder of ground ways to a point 36 feet beyond low water mark, applied by means of cofferdams three to four days before the launch, and touched up the day before on account of damage from ice—Tallow mixed with lard oil.

Lubricant on sliding ways, applied two to three weeks before launching —Forward 80 feet thin coat of stearine, whole length with launching grease smeared on lightly.

Lubricant on pivoting surface under fore poppets—A mixture of half stearine and half tallow applied 9/16-inch thick.

Removing blocks, etc.—Some of the blocks at ends of vessel and most of the shores were removed the day before the launch.

Wedges were set by mauls and alternate keel blocks removed, starting at 7:30 A. M. on day of launch. Rallies on the wedges, using rams, were made at 10:00, 10:11, 10:22 and 10:32 A. M., the last block was out at 12:10 P. M., dog shores dropped at 12:13 and ship released at 12:15 P. M.

About 280 men were employed below the ship; some 40 of these afterward went on board, making about 120 men on the ship at time of launch.

Vessel was launched just as tide was turning ebb; there was a moderate breeze from the southwest.—"International Marine Engineering."

NEW DRY DOCK FOR SAN FRANCISCO.

Two dry docks are now maintained on the Pacific Coast for the vessels of the United States Navy; one at Mare Island, on a branch of San Francisco Bay, the other at Bremerton on the Puget Sound near Seattle. With the opening of the Panama Canal naval operations on the Pacific assume a much more important aspect than heretofore. Neither of the above docks will be adequate for the superdreadnaughts that will frequently need overhauling on the Coast. For this reason a contract has been executed between the United States and the Union Iron Works Dry Dock Co., of San Francisco, whereby the latter corporation will construct a $2,000,000 dry dock in San Francisco Harbor, under the guarantee that the Government will furnish at least $50,000 in business each year for six successive years.

The new dock will be constructed at Hunter's Point, a promontory extending into the bay from the east shore of San Francisco, where

two small dry docks have been in service for a number of years. The foundation will be of solid rock and the structure of reinforced concrete, specially designed to withstand severe earthquake shock. Its length over all is 1,096 feet, breadth between vertical walls 120 feet, breadth to top of altars 140 feet 8 inches and depth from mean high water to top of sill 42 feet 6 inches. Its bow is elliptical and its sides parallel. They arise vertically from the floor to within 12 feet of the top of the coping, where altars extending for almost the entire length on both sides increase the width from 120 feet to 140 feet 8 inches.

From the center to the side drainage gutters the concrete floor has a chamber of 12 inches. On it are the center keelson working platform and bilge blockways, both of wooden construction. Over the rudder pit, located near the outer end of the dock, the center keelson can be removed in sections.

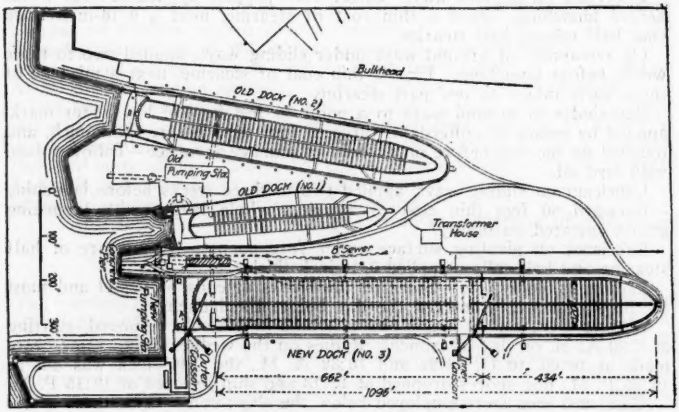


FIG. 1.—LOCATION OF TWO OLD AND ONE NEW DRY DOCKS AT SAN FRANCISCO.

The dock will be closed by an outer caisson and opened by floating and sliding this into a transverse recess in the side of the concrete structure. A similar recess and second caisson are located forward of the center, so that the dock may be used as a whole by sliding only the outer caisson into position; or the upper end alone may be used by closing the middle caisson, or both ends may be used independently at the same time by sliding closed both caissons. The center caisson recess is drained through a tunnel 4 feet 6 inches in diameter, which leads to the pump pit. While the caissons themselves are essentially of the sliding-box type, they can also be floated from one place to another and thus divide the structure in compartments of any desired length. They are designed so as to have ample stability without fixed ballast both when floating light or when partially flooded. This is accomplished by transverse partitions which divide the caissons themselves into three compartments, the middle one of which can be flooded or emptied without lowering the metacenter below the center of gravity.

Four inclined tunnels 10 feet in diameter, two on each side of the dock leading to the forward and rear sections, and two open-curved stairways at the elliptical bow, provide ready access to the interior. The

tunnels are closed by butterfly valves. To unwater the dock these are opened and the water allowed to drain to the pump pit, from which it is by-drawn by 54-inch vertical centrifugal pumps of the single-stage, volute type. Each pump has a capacity of 75,000 gallons per minute, pumping against a head up to 42 feet. They are direct connected to 750-H.P. motors, which operate at 250 r.p.m. Pump casings are of the volute form, of cast iron, in sections provided with vertical and horizontal joints, so that they may be easily removed through openings in the motor floor above. Impellers of the inclosed type will be of a bronze with a single-bottom opening, and are designed to eliminate as far as possible objectionable end thrust. The top heads are sufficiently large to permit the removal of the impellers for repairs.

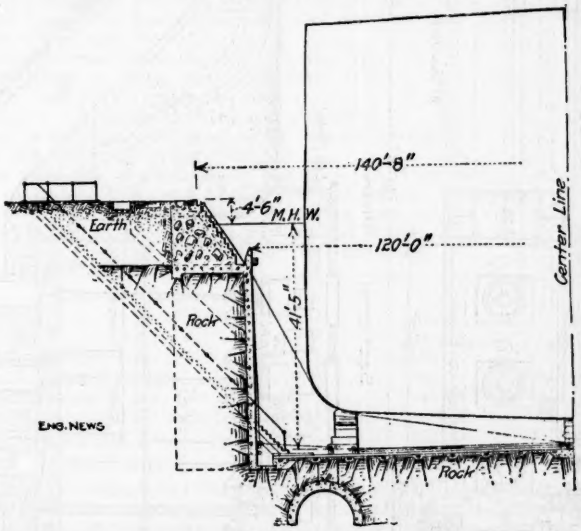


FIG. 2.—HALF-SECTION THROUGH NEW SAN FRANCISCO DRY DOCK.

Pump house and pit are to be located near the outer end of the dry dock. The top of the pit will be 48 feet below high water or 62 feet 6 inches below the top of the dock coping. Besides the four 54-inch pumps for unwatering the docks, the equipment comprises two 15-inch pumps for draining the tunnels, an 8-inch salt-water high-pressure pump, a priming pump and the operating gear for the gate valves and for the butterfly valves which close the tunnels leading to each section of the dock.

For flooding the dock a tunnel 12 feet in diameter, controlled by a butterfly valve, leads from the bay to the pump pit. Thence the water flows into the dock through the same tunnels by which the structure is unwatered. The operating gear which contains the flooding butterfly valve is housed separately from the main pumps in a small concrete building. The dock with tunnels has a capacity of 5,715,000 cubic feet and with the four large pumps can be emptied in less than two hours and twenty minutes. It can be flooded in about thirty minutes.

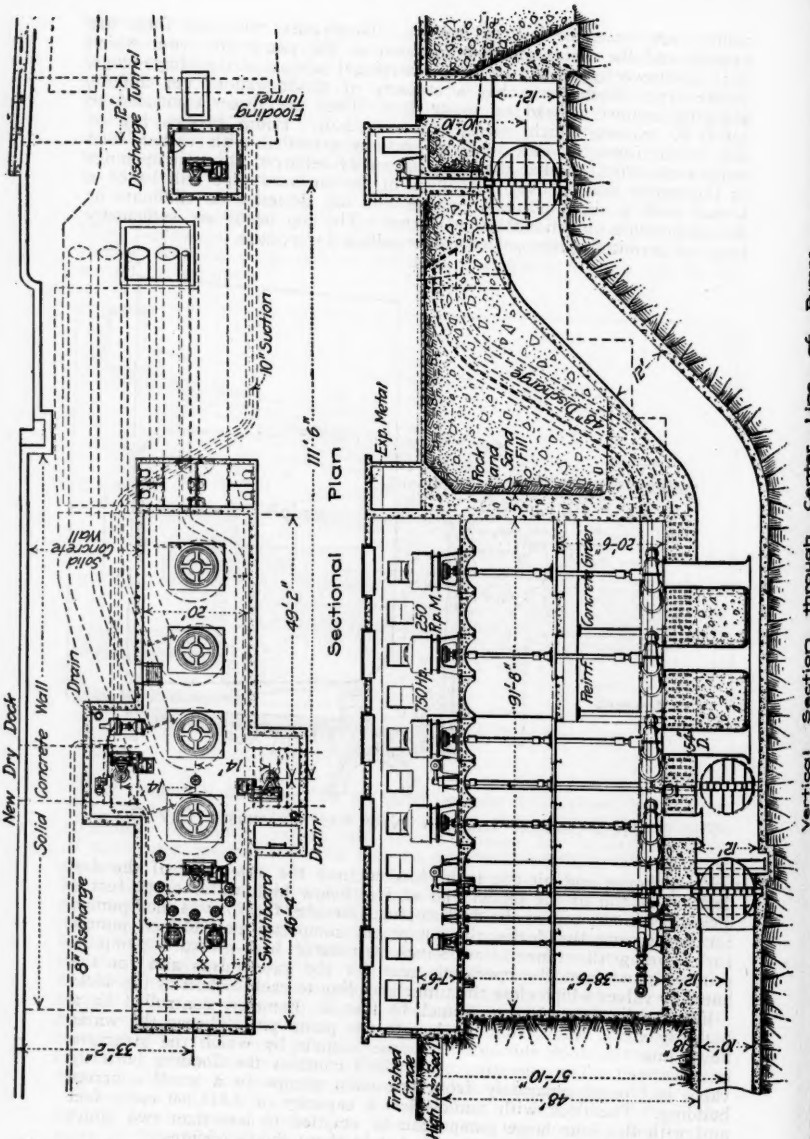


FIG. 3.—SECTION THROUGH AND PLAN OF PUMP HOUSE, SAN FRANCISCO DRY DOCK.

On the port side of the dock will be a reinforced-concrete pier, with railroad tracks so arranged that cars may be landed from barges on the bay. A reinforced-concrete wharf on the starboard side approximately 450 feet in length and 100 feet in width at the outer end, will furnish ample wharfage facilities. Electric power will be used for the pumps and machinery as well as for the compressors that will operate pneumatic implements used in ship repair. A transformer house will therefore also be required. This will be of concrete and will be erected on the port side, opposite the inner caisson recess.

Below is a tabular description of the dock and caissons:

Length from outer meeting face to head of dock, feet	1,096
Length from inner meeting face to head of dock, feet	434
Length from outer meeting face to inner meetings face, feet	662
Width of caissons, feet	22
Usable length of outer section of dock, feet	640
Usable length of inner section of dock, feet	434
Breadth between vertical walls, feet	120
Breadth at top in way of altars, feet and inches	140–08
Height of coping above higher water, feet and inches	4–06
Outer sill below high water, feet	40
Depth from top of sill to top of coping, feet and inches	44–06
Top of keelson below top of sill, feet and inches	1–05
Height of keel blocks above top of keelson, feet	4
Top of keel block above top of sill, feet and inches	2–07
Top of keel block below high water, feet and inches	37–05
Flood camber, inches	12

	Inner caisson.	Outer caisson.
Length, molded, feet	124	124
Breadth, molded, feet	22	22
Extreme height at side, feet and inches	48–06	46–06
Light draft from third deck, feet and inches	8–06	8–03
Light displacement, tons	620	620

Accessories included in the specifications are keel blocks, bilge blocks, air and salt-water piping, fresh-water hydrants, electric conduits, electric capstans, one 50-ton electric self-slewing stiff-leg traveling crane, cast-iron bitts, belaying pins, ladders, blocks, etc.

The dock was designed and specifications prepared by Hugo P. Frear, Architect for the Union Iron Works Co. and Chief Engineer for the Union Iron Works Dry Dock Company.

The new San Francisco Dry Dock is among the five new dry docks which have a total length of 1,000 feet or over, all of which can dock any vessel now afloat. Two of these docks, the Gladstone at Liverpool and the Alexandria at Bombay, are completed and those at Boston and Levis are now under construction. The general dimensions of the five are as follows:

	Length.	Breath.	Depth H.W.
Boston, Mass., feet	1,200	120	44.8
Levis, Que., feet	1,120	120	40.0
San Francisco, Calif., feet	1,096	120	42.5
Gladstone, Liverpool, feet	1,050	120	46.0
Bombay, India, feet	1,000	100	33.3

—"Engineering News."

SURPRISING FAILURE OF STEEL SHIP PLATES.

Considering the treatment which ship plates must undergo, both in the shipyard while being flanged and riveted, and afterwards in the ship in service when the plates are subjected to unknown stresses, the necessity for a method of testing the steel of which the plates are made to determine its suitability for the purpose is of the utmost importance. Lloyd's Rules for testing shipbuilding materials are generally regarded as reliable, and steel which is passed by Lloyd's surveyors is generally accepted as suitable for the purposes intended without further investigation. A case is cited, however, by Mr. W. J. B. Wilson in a paper recently read before the North East Coast Institution of Engineers and Shipbuilders, in which a consignment of steel ship plates, after passing Lloyd's tests and being characterized by the surveyor as "excellent," failed in a surprising manner shortly after being worked into the ship.

In this case the shipbuilding firm received an order for an ice-breaking passenger and cargo steamer to be built to Lloyd's highest class under special survey. The vessel was begun in November, 1907, but, owing to delay in obtaining the material, the shell plating was not begun until the end of December. B strake was first worked, but, owing to the difficulty with the flanging of the garboard strake plates, several of which cracked, the rest of the shell was practically completed before the garboard strakes were put in place.

The garboard strake plates which cracked were carefully examined, but as the results of both bending and tensile tests were excellent, the failure at the time was ascribed to the severe cold weather prevailing, the temperature being from —13 to —18.4 degrees F.

The riveting of the shell was well under way before the keel riveting was begun, but, after a few garboard plates had been riveted, cracks were noticed between the rivets and the edge of the plate in the flanged portion. These plates were condemned by the Lloyd's surveyors and were cut out. During the process two of them cracked badly in the neighborhood of the keel rivets, and the astonishing fact developed that a single blow with an ordinary hand hammer was sufficient to knock pieces out of the flanged portion.

This sudden change in these plates, which had withstood flanging, punching, riveting and, in some cases, calking, was very remarkable, and the job of riveting the keel was at once stopped until a thorough hammer test of the flanged portion of all the remaining garboard plates had been made. When this proved perfectly satisfactory, the riveting was resumed and only one or two small cracks developed.

About this time severe cold weather set in again, and on January 11, 1908, one of the garboard plates, which had been riveted in the ship for a period of three weeks, was found to be badly cracked. The crack started from a rivet hole in the flanged portion and went off into the plate in a transverse direction, being about 10 inches long and about 3/32 inch open at the widest part. This was clearly a case of spontaneous rupture.

When this plate was cut out the material in way of the keel rivets cracked in the same way as that described above, and a new hammer test was made with startlingly different results from the previous one, as every plate in the garboard strakes, with the exception of those previously replaced, cracked and in some cases pieces fell out. These plates were, therefore, condemned and cut out.

So far the cracks had been entirely confined to the flanged portion of the garboard strakes, but during the cutting out of the rivets connecting the garboard plates to B strake several plates in B strake also cracked. A new survey was then made by Lloyd's and pieces cut from the plates in the ship rolled from different charges were tested. All of the tests proved satisfactory to the surveyor, but after these tests the astonishing

fact developed that one blow of a heavy hammer was sufficient to knock large pieces out of flanged portions of the shell plates. The net result of this survey was that all plates rolled from the same charge as the garboard strakes, together with several plates which had bad surface defects, were condemned. The latter had been filled with some composition which fell away during riveting. One plate had two large holes which had been filled up. A 6-inch feeler pushed into these holes penetrated 1½ inches, while the makers' brand was not 12 inches away on the same side of the plate.

The condemned plates, twelve in number, were in various strakes of the shell plating, and during the removal, in spite of the care taken, the trouble spread over the whole of the bottom of the vessel. As an example, one of the plates in E strake, ½ inch thick, which had been punched, sheared, bent, riveted and calked without any trouble, had to have the rivets in its lower edge removed in order to take out a plate in D strake. When the rivets were center-punched preparatory to drilling them out, the plate in E strake cracked, although it was not actually touched by the hammer, which was only an ordinary hand hammer. In the edge of this plate, when all the rivets had been drilled out and driven, sixteen cracks were found.

This plate was afterwards examined by Lloyd's surveyors, when it was plainly shown that one blow with a sledge hammer was sufficient to cause cracks to appear between the edge and butt rivet holes; but, although the hammering was continued, not a single crack would travel far into the plate away from the rivet holes. The failure still continuing, a new survey was made by two of Lloyd's surveyors, one of whom had previously tested the steel. Tests were made, but these, like all the others, failed to throw the slightest light on what was really wrong with the steel. The treatment of the steel was criticised, but it was subsequently established that the workmanship in the shipyard was above reproach.

After these tests had been made the surveyors maintained that as the steel passed the tests laid down in the rules, they were not justified in blaming the material unless a test could be devised which would in their presence prove the steel to be at fault. Meanwhile, the author of the paper, who had made scores of tests with this object in view, had found one that gave the required results, and which may prove useful to others in like circumstances.

This test consisted of placing a butt strap which had not been worked into the vessel and a plate of material made in a Swedish steel works in a mixture of snow and salt, which reduced the temperature of the plates to —4 degrees F. The plates were then quickly punched on one side for double riveting and riveted together, care being taken that the edges of the plates opposite the holes were kept cool with ice in order to represent as closely as possible the conditions when working the steel in a low temperature. After the plates were allowed to cool down the rivets were driven out, during which operation the plate from the butt strap cracked badly and a piece fell out. The plate from the Swedish steel works, however, did not show the least signs of cracks.

From another plate two strips 2⅜ inches wide were cut and four holes ⅝-inch diameter and 4½ diameters apart were punched and the strips riveted together. The same was done with two similar strips, but with drilled holes, the temperature at the time being about 39.2 degrees F. After cooling, the strips were bent through an angle of 25 degrees and the outer strip was found to be broken right through in the punched sample and cracks were found in the drilled sample.

These butt-strap tests were sufficient to convince all concerned that the material was really entirely spoiled by riveting, and therefore the builders were relieved from all blame, the workmanship being characterized as "first class." A further proof that the material was bad was the very

conclusive one of the new Swedish material, which, although worked in the same way, gave no trouble at all.

From the foregoing, it is evident that the ordinary methods of testing in this particular case were insufficient to detect the poor quality of the material which was being used, and dependence upon such tests under like conditions certainly seems to place shipbuilders and others in a position in which they run grave risks. The test made by Mr. Wilson in which a mixture of snow and salt was used certainly detected the fault in this particular steel, and is therefore worthy of consideration. Subsequent tests of samples of this steel made by Professor J. O. Arnold of the University of Sheffield, showed that from a chemical point of view the steel was not of very good quality, and that it appeared to have been overheated in the manufacture and gravely injured by the operation.—"International Marine Engineering."

FRACTURE OF PLATES ON U. S. S. *O'BRIEN*.

From Report of Inspector of Machinery.

The U. S. S. *O'Brien* had nearly completed her standardization trials off the Delaware Breakwater on December 21, 1914, when it was found that a plate on the starboard side of the vessel, below the load water line, was ruptured. The after compartment of the vessel below the deck flat was filled with water, thereby increasing the displacement and seriously retarding the speed of the vessel. Subsequent examination in dry dock showed that the B and C plates on both sides, abreast the propellers, were cracked, and a piece on the starboard side torn out and bent backward.

The starboard plate cracked near the edge of the angle iron of frame 162 for a distance of 22 inches, and gradually bent outward and rearward by the pressure of water due to speed of the vessel. The crack was quite regular and parallel with the edge of the flange and clear of the rivet holes of the seam, as shown by plates A and B. Plate C shows how the cracks progress in the early stages.

These cracks were probably caused by the vibration of the vessel and the panting of the hull plates; the fractures occurring directly next to a frame stiffened by a bulkhead at that point.

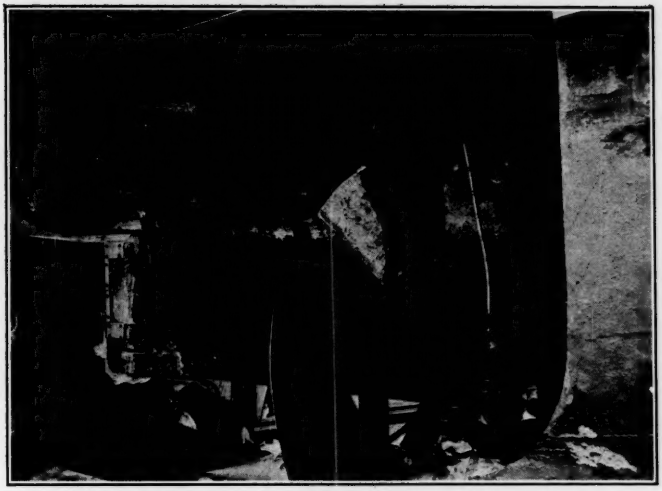
EPICASSIT.

A RECENT GERMAN INVENTION FOR COATING IRON AND STEEL WITH TIN, LEAD, ZINC, ETC., BY PAINTING AND EXTERNAL HEATING.

By Charles H. Proctor.

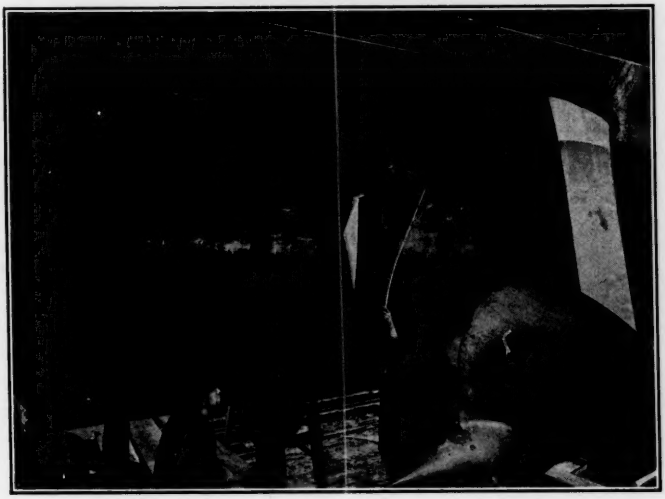
Epicassit is a recent German invention for coating iron or steel with pure tin, tin and lead or a purely rust-free coating of tin, lead and zinc. In consists of a very finely-powdered metal which is mixed with an oil that acts as a flux. It is painted upon the metal surface in the ordinary manner with a brush and then heat is applied to the surface until the applied metal melts, when it becomes thoroughly amalgamated with the surface metal producing an extremely firm and durable coating.

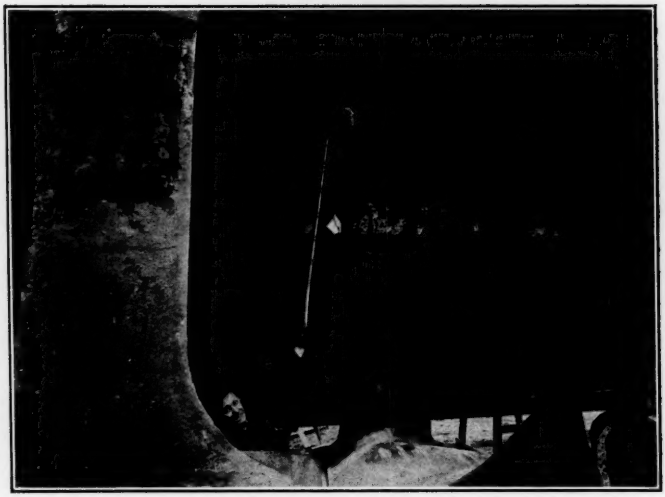
Epicassit does not run when being melted, so that articles of any shape or size, in any position, can be treated without being dismantled or removed from their permanent positions.



U. S. T. B. D. "O'BRIEN"—STARBOARD SIDE.

Forward end of break is vertical on frame 162, about 22 inches high, and extends aft 15 inches on top and 9 inches on bottom. The top is between the 9-foot and 10-foot water lines and the bottom is between the 7-foot and 8-foot water lines. The break apparently started with the vertical rupture at frame 162. The forward end of break is about in line with center of propeller. The distance from the hull, at the break, to the propeller tip circle is about 18 inches.





U. S. T. B. D. "O'BRIEN"—PORT SIDE.

Vertical crack through plate on frame 162 at about same height as break on starboard side. The rag shown in the crack was drawn in as the water ran out in the dry dock.

This is one of the great advantages of Epicassit. The material will fill a distinct field and will prove of much value in the metal trades. It will enable any one to coat a metal surface with tin or its alloys in a very efficient manner, and is as economical as the older method of immersing in molten metal. Manufacturers who have occasionally to coat articles with tin or its alloys will appreciate the value of the material, as no special apparatus is required or special workman needed to produce results with the method.

Epicassit comes in several alloys, but the same oil flux is used for all.

A. Grade consists of pure Banca tin, guaranteed free from lead.

B. Grade alloy consists of two parts tin and one part lead.

C. Grade alloy consists of two parts lead and one part tin.

(C.1) Grade consists of 95 per cent. lead and 5 per cent. tin.

E. Grade consists of 35 per cent. tin, 15 per cent. lead and 50 per cent. zinc; this grade produces an entirely rust-free protective coating for articles of iron and steel.

These various grades enable the manufacturer to coat articles with any protective coating desired, from pure tin to a combination of tin-lead and zinc without any special plant. Hundreds of manufacturers in Germany are using the material. Every plumber in the United States will appreciate the value of the material. Because of the simplicity of application it will enable them to do work that heretofore they would have to refuse because of not being properly equipped to coat articles to be retinned or coated with the other alloys mentioned.

Grade A can be used where any article or part is desired to be tinned. Parts of machinery used in producing articles of food, milk cans, dairy and brewery machinery, drinking-water receptacles, heating and cooling tubes, and apparatus of all sizes in breweries, bakeries, meat packing, fruit preserving, candy making utensils and machines.

Grade B.—For any articles that come in contact with food products, for tinning bearings, as a solder for switchboard and overhead trolley connections in electric railroad operations.

Grade C.—For parts of accumulators as a protective coating against acid fumes, iron and steel window frames, textile dyeing, printing, bleaching and spinning-mill machinery, and parts can be coated to advantage as well as calendars in paper mills.

C1. Grade.—For any articles previously coated with lead gives a protective coating for metal parts coming in contact with acids equal to pure lead.

E Grade.—Gives a more perfect protective coating than any form of galvanizing against oxidation and sea water. It is particularly recommended for galvanizing articles which are to be bent, stamped, cut or corrugated. An absolute rust-protective coating for bridges, cranes, etc. When "E." Epicassit is applied before assembling, girders, plates or any other surface can be coated in or out of position. Its advantages are enumerable over any method now in vogue for the purpose of coating metals from an external source.

Epicassit is now obtainable in this country from Hess and Son, 1031 Chestnut Street, Philadelphia, Pa.—"The Metal Industry."

NAVAL VESSELS.

UNITED STATES NAVAL VESSELS UNDER CONSTRUCTION.

DEGREE OF COMPLETION.

No.	Vessel.	Building yard.	Engines.	No. shafts.	Speed, knots.	Percentage machinery completed 1915.		Hull com. Feb. 1, 1915.
						Jan. 1	Feb 1.	Per ct.
	BATTLESHIPS:							
36	*Nevada*	Fore River S. Co.	Curtis turbine	2	20.5	87.19	89.40	84.6
37	*Oklahoma*	New York S. Co.	Reciprocating	2	20.5	88.65	90.72	87.2
38	*Pennsylvania*	Newport News Co.	Cur. trb. grd. cr.	4	21	48.73	51.98	67.7
39	*Arizona*	Navy Yard, N. Y.	Pars. trb. grd. cr.	4	21	27.92	31.34	48.1
40	*California*	Navy Yard, N. Y.	.....	4	21	...	...	...
41	*Mississippi*	Newport News Co.	Cur. trb. grd. cr.	4	21	...	1.23	6.0
42	*Idaho*	New York S. Co.	Pars. trb. grd. cr.	4	21	...	1.32	9.9
	DESTROYERS:							
45	*Downes*	New York S. Co.	Curtis trb. & rec.	2	29	98.15	99.41	99.2
51	*O'Brien*	Wm. Cramp & Sons	Cramp trb. & rec.	2	29	95.61	95.90	93.3
52	*Nicholson*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	89.56	91.99	90.2
53	*Winslow*	Wm. Cramp & Sons.	Cramp trb. & rec.	2	29	84.65	86.65	87.0
55	*Cushing*	Fore River S. Co.	Curtis trb. grd. cr.	2	29	83.75	89.69	84.0
56	*Ericsson*	New York S. Co.	Pars. trb. & rec.	2	29	90.22	93.39	92.8
57	*Tucker*	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	32.07	40.58	33.2
58	*Conyngham*	Wm. Cramp & Sons	Pars. trb. grd. cr.	2	29.5	38.37	41.42	54.3
59	*Porter*	Wm. Cramp & Sons.	Pars. trb. grd. cr.	2	29.5	36.10	39.20	50.8
60	*Wadsworth*	Bath Iron Works.	Pars. trb. gearing.	2	30	81.77	87.14	78.6
61	*Jacob Jones*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	54.74	61.23	52.2
62	*Wainwright*	New York S. Co.	Pars. trb. grd. cr.	2	29.5	56.51	62.29	51.7
63	.....	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	...	3.03	6.4
64	.....	Fore River S. Co.	Curtis trb. grd. cr.	2	29.5	...	3.03	6.4
65	.....	Bath Iron Works.	Pars. trb. grd. cr.	2	30	...	...	...
66	.....	Bath Iron Works.	Pars. trb. grd. cr.	2	30	...	...	...
67	.....	Wm. Cramps & Sons.	Pars. trb. grd. cr.	2	29.5	...	...	...
68	.....	Navy Yard, Mare Isl'd.	Pars. trb. grd. cr.	2	29.5	...	...	...
	FUEL SHIPS:							
13	*Kanawha*	Navy Yard, Mare Isl'd.	Reciprocating	2	14	80.60	88.00	93.9
14	*Maumee*	Navy Yard, Mare Isl'd.	Diesel	2	14	31.59	33.30	73.9
	SUBMARINES:							
31	*G-3*	Navy Yard, N. Y.	Diesel-Sulzer	2	14	84.00	85.00	86.7
40	*L-1*	Fore River S. Co.	Diesel-New Lond	2	14	93.90	95.77	89.6
*41	*L-2*	Fore River S. Co.	Diesel-New Lond	2	14	93.42	95.47	84.6
42	*L-3*	Fore River S. Co.	Diesel-New Lond	2	14	92.87	94.84	75.5
43	*L-4*	Fore River S. Co.	Diesel-New Lond	2	14	91.78	94.15	76.0
44	*L-5*	Lake Co., Bridgeport	Diesel-Sulzer	2	14	4.50	5.03	58.2
45	*L-6*	Lake Long Beach, Cal.	Diesel-Sulzer	2	14	4.50	4.98	52.7
46	*L-7*	Lake Long Beach, Cal.	Diesel-Sulzer	2	14	4.50	4.98	51.6
47	*M-1*	Fore River S. Co.	Diesel-New Lond	2	14	86.30	88.34	63.4
48	*L-8*	Navy Yard, Portsmouth	Diesel-Sulzer	2	14	...	...	3.0
49	*L-9*	Fore River S. Co.	Diesel-New Lond	2	14	66.66	73.13	50.0
50	*L-10*	Fore River S. Co.	Diesel-New Lond	2	14	59.34	71.76	45.6
51	*L-11*	Fore River S. Co.	Diesel-New Lond	2	14	33.96	48.53	33.2
	SUBMARINE TENDER:							
2	*Bushnell*	Seattle Con. & D. D. Co.	Pars. trb. gearing	1	14	60.73	66.69	83.3
	DESTROYER TENDER:							
2	*Melville*	New York S. Co.	Pars. trb. gearing	1	15	69.39	72.00	78.3
	Transport	Navy Yard, Phila.	Reciprocating	2	14	...	1.85	3.4
	Supply ship	Navy Yard, Boston	Reciprocating	2	14	1.03	1.33	15.8
	PANAMA COLLIERS:							
	Ulysses	Md. Steel Co.	Reciprocating	2	14	80.13	87.96	87.2
	Achilles	Md. Steel Co.	Reciprocating	2	14	64.35	75.19	77.1
	Oil Barges 8 and 9.	Navy Yard, Mare Isl'd.	.....	...	...	41.70	69.30	...
	Oil Barge 7	Navy Yard, Norfolk	.....	...	...	82.00	85.00	...

U. S. S. *DOWNES.*

The U. S. S. *Downes* successfully completed her preliminary trials off the Delaware Breakwater, January 5, 1915. An average speed of 29.071 knots per hour was maintained on the four-hour full-speed trial. Delivery of vessel has been authorized, Navy Yard, Philadelphia, Pa.

U. S. S. *O'BRIEN.*

The U. S. S. *O'Brien* successfully completed her preliminary trials (second trial) off the Delaware Breakwater, February 6, 1915. An average speed of 29.15 knots per hour was maintained in the four-hour full-speed trial.

SUBMARINE TENDER *FULTON.*

The standardization trials were made on the Provincetown course, and the highest speed on the average of five runs was 12.78 knots while the contract called for but 12¼ knots. The anchor tests and maneuvering trials were equally successful, particularly in reversing at full speed and bringing the vessel to a dead stop. The fuel test at cruising speed proved the *Fulton's* motor plant to be economical, while the working of the engine and all auxiliaries was perfect. Her fuel-carrying capacity gives the *Fulton* a cruising radius of 10,000 miles and, as compared with the fuel consumption of a steam vessel, the *Fulton,* on a given amount of fuel, could make four to five times the distance that a coal-fired vessel could. To this advantage must also be added the economy in fuel bills and the saving in the number of men necessary to handle the machinery.

The "Rudder" for January contained a detailed description of this vessel together with outboard and inboard profile and accommodation, diagrams and other illustrations in connection therewith.—Exchange.

NAVAL REINFORCEMENTS.

The additions which have been, and will be made to the belligerent fleets since the commencement of hostilities demonstrate the fact that the longer the war lasts the greater will be the superiority of the British over the German Navy. The following is a list of all classes of ships so far as is known which have been or will be completed before the end of 1915.

BRITAIN.

BATTLESHIPS COMPLETED.—(1) *Agincourt,* 27,500 tons, fourteen 12-in. guns; (2) *Erin,* 23,000 tons, ten 13.5-in. guns; (3) *Benbow,* 25,000 tons, ten 13.5-in. guns; (4) *Emperor of India,* 25,000 tons, ten 13.5-in. guns. BATTLESHIPS BUILDING.—(5) *Queen Elizabeth,* 27,500 tons, eight 15-in. guns; (6) *Warspite,* 27,500 tons, eight 15-in. guns; (7) *Valiant,* 27,500

tons, eight 15-in. guns; (8) *Barham*, 27,500 tons, eight 15-in. guns; (9) *Malaya*, 27,500 tons, eight 15-in. guns; (10) *Royal Sovereign*, 26,000 tons, eight 15-in. guns; (11) *Royal Oak*, 26,000 tons, eight 15-in. guns; (12) *Revenge*, 26,000 tons, eight 15-in. guns; (13) *Ramillies*, 26,000 tons, eight 15-in. guns; (14) *Canada*, formerly *Almirante Latorre* (building for Chili), 28,000 tons, ten 14-in. guns. BATTLE CRUISERS COMPLETED.—*Tiger*, 28,000 tons, eight 13.5-in. guns. CRUISERS (nearly all completed).—(1) *Arethusa*, 3,520 tons, two 6-in. and six 4-in. guns; (2) *Undaunted*, 3,520 tons, two 6-in. and six 4-in. guns; (3) *Aurora*, 3,520 tons, two 6-in. and six 4-in. guns; (4) *Galatea*, 3,250 tons, two 6-in. and six 4-in. guns; (5) *Inconstant*, 3,520 tons, two 6-in. and six 4-in. guns; (6) *Royalist*, 3,520 tons, two 6-in. and six 4-in. guns; (7) *Penelope*, 3,520 tons, two 6-in. and six 4-in. guns; (8) *Phaeton*, 3,520 tons, two 6-in. and six 4-in. guns; (9) *Calliope*, 3,800 tons, three 6-in. and six 4-in. guns; (10) *Caroline*, 3,800 tons, three 6-in. and six 4-in. guns; (11) *Carysfort*, 3,800 tons, three 6-in. and six 4-in. guns; (12) *Champion*, 3,800 tons, three 6-in. and six 4-in. guns; (13) *Cleopatra*, 3,800 tons, three 6-in. and six 4-in. guns; (14) *Comus*, 3,800 tons, three 6-in. and six 4-in. guns; (15) *Conquest*, 3,800 tons, three 6-in. and six 4-in. guns; (16) *Cordelia*, 3,800 tons, three 6-in. and six 4-in. guns. MONITORS (completed).—(1) *Humber*, 1,200 tons, two 6-in. and two 4.7-in. guns; (2) *Severn*, 1,200 tons, two 6-in. and two 4.7-in. guns; (3) *Mersey*, 1,200 tons, two 6-in. and two 4.7-in. guns; (4) Unnamed, 4,900 tons, two 9.4-in., four 6-in. and six 4-in. guns; (5) Unnamed, 4,900 tons, two 9.4-in., four 6-in. and six 4-in. guns. DESTROYERS (Flotilla Leaders) completed.—*Broke, Faulkner*, 1,600 tons, six 4-in. guns; *Marksman, Lightfoot*, and probably more purchased. DESTROYERS completed.—*Lance, Laverock, Leonidas, Milne, Moorsom, Mastiff, Lookout, Lucifer, Meteor, Minos, Miranda, Manly, Morris, Mansfield, Myngs, Murray, Matchless.* SUBMARINES.—Unknown.

GERMANY.

BATTLESHIPS.—(1) *König*, 25,800 tons, ten 12-in. guns; (2) *Kronprinz*,* 25,800 tons, ten 12-in. guns; (3) *Markgraf*, 25,800 tons, ten 12-in. guns; (4) *Grosser Kurfürst*, 25,800 tons, ten 12-in. guns. BATTLE CRUISERS.—(1) *Derflinger*, 26,600 tons, eight 12-in. guns; (2) *Lutzow*, 26,600 tons, eight 12-in. guns; (3) *Ers. Hertha*,* 26,600 tons, eight 12-in. guns; (4) ex. Greek *Salamis*,* 19,500 tons, eight 14-in. guns. CRUISERS.—(1) *Karlsruhe*, (2) *Rostock*, (3) *Grandenz*, (4) *Enz. Niobe*,* (5) *Enz. Gefion*,* (6) *Enz. Gazele*,* (7) Unnamed, 4,500 tons; (8) Unnamed, 4,500 tons, eight 5-in. guns (building for Russia). DESTROYERS AND SUBMARINES.—Uncertain.

FRANCE.

BATTLESHIPS.—(1) *France*, 23,467 tons, twelve 12-in. guns; (2) *Paris*, 23,467 tons, twelve 12-in. guns; (3) *Bretagne*,* 23,550 tons, ten 13.4-in. guns; (4) *Lorraine*,* 23,550 tons, ten 13.4-in. guns; (5) *Provence*,* 23,550 tons, ten 13.4-in. guns. DESTROYERS.—About nine completing.

JAPAN.

BATTLESHIPS.—*Fu So*,* 30,600 tons, twelve 14-in. guns. BATTLE CRUISERS.—*Hi-Yei*, 27,500 tons, eight 14-in. guns; *Haruna*,* 27,500 tons, eight 14-in. guns; *Kirishima*,* 27,500 tons, eight 14-in. guns. DESTROYERS.—Two.

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* Building.

RUSSIA.

BATTLESHIPS.—(1) *Pollava,* 23,300 tons, twelve 12-in. guns; (2) *Petropavlovsk,* 23,300 tons, twelve 12-in. guns; (3) *Sevastopol,* 23,300 tons, twelve 12-in. guns; (4) *Ganfoot,* 23,500 tons, twelve 12-in. guns; (5) *Ekaterina II.,** 22,500 tons, twelve 12-in. guns; (6) *Imperatrza Maria,** 22,500 tons, twelve 12-in. guns; (7) *Alexander III.,** 22,500 tons, twelve 12-in. guns. CRUISERS.—(1) *Svietlana,* 6,750 tons, twelve 6-in. guns; (2) *Greig,* 6,750 tons, twelve 6-in. guns; (3) *Bootakof,* 6,750 tons; twelve 6-in. guns; (4) *Spiridoff,* 6,750 tons, twelve 6-in. guns (all not likely to be finished during the war).

AUSTRIA.

BATTLESHIPS.—*Szent Istvan,** 20,000 tons, twelve 12-in. guns.

NEW JAPANESE DESTROYERS.

The two ocean-going torpedo-boat destroyers, *Kawakaze* and *Urakase,* which Yarrow and Co., Ltd., will shortly launch at Glasgow for the Japanese Government, are of exceptional engineering interest, because while in each the main propelling machinery is to consist of an installation of steam turbines, each will also have for cruising purposes, two Diesel engines of 1,200 B.H.P. The twin turbines will each be of 12,000 H.P., and when the vessels are running at cruising speeds the twin screws will be driven by the oil engines, which it is understood will operate the propellers by means of solid shafts working inside tubular shafts.

The Diesel engines, which are being supplied by the Burmeister and Wain (Diesel system) Oil Engine Co., of Glasgow, are of the six-cylinder four-cycle type, and they are designed to give the vessels a speed of from 13 to 14 knots. When the turbines are in use the speed will be about 34 knots. The advantage of the cruising machinery lies in the great saving in fuel which will be possible and the rapidity with which the vessels can be got under way.—"Page's Engineering Weekly."

STRENGTH OF NAVAL POWERS.

The data given below as to the relative strength of the principal naval powers were furnished by the Office of Naval Intelligence, Navy Department, as of date July 1, 1914. Owing to the state of war in Europe the Office of Naval Intelligence was unable to furnish any definite information of the relative strength of the principal naval powers of the world later than July 1, 1914.

The figures given are incorporated in the Navy Year Book, just issued as a Senate document, which is a compilation of annual Naval Appropriation laws from 1883 to 1914, prepared by J. D. Knight, Secretary of the Senate Committee on Naval Affairs. It is shown that the United States Navy, on the basis of ships completed on July 1, 1914, was third among the navies of the world in respect to tonnage. Great Britain was first and Germany second. When vessels under construction on July 1 are completed the United States Navy will be in fourth place, surpassed by Great Britain, Germany and France. Figures are lacking, however, to show the progress in naval increase among belligerents in the present war in Europe since its commencement, and it is well known that both England and Germany have been increasing their naval power as rapidly as possible.

* Building.

WARSHIP TONNAGE OF THE PRINCIPAL NAVAL POWERS.

[Number and displacement of warships built and building, of 1,500 or more tons, and torpedo craft of more than 50 tons.]

Type of vessel.	Great Britain (including colonial vessels).				Germany.				United States.				France.			
	Built.		Building.		Built.		Building.		Built.		Building.		Built.		Building.	
	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).
Battleships (dreadnaught type) [1]	20	423,350	16	421,750	13	285,770	7	187,164	8	189,650	4	117,800	4	92,368	8	193,656
Battleships (predreadnaught) [2]	40	589,385	...	...	20	242,800	...	...	22	309,282	...	...	18	262,675	...	...
Coast-defense vessels [3]	...	...	...	...	2	8,168	...	...	4	12,900	...	...	1	8,800	...	...
Battle cruisers [4]	9	187,800	1	28,500	4	88,749	4	112,000	...	...	...	...	...	...	...	...
Armored cruisers	34	406,800	...	...	9	94,245	...	...	11	149,295	...	...	20	201,724	...	...
Cruisers [5]	74	382,815	17	67,000	41	150,747	5	26,900	14	66,410	...	...	9	46,095	...	...
Torpedo-boat destroyers	167	125,850	21	21,770	130	67,094	24	14,400	51	35,068	11	11,956	84	35,812	3	2,653
Torpedo boats	49	11,488	...	...	...	...	...	...	13	2,528	...	...	135	13,426	...	...
Submarines	75	30,362	22	17,236	27	14,140	18	14,400	30	...	[7]19	...	64	27,940	22	14,766
Total tons built and total tons building	...	2,157,850	...	556,256	...	951,713	...	354,864	...	765,133	...	129,756	...	688,840	...	211,075
Total tons built and building		2,714,106				1,306,577				894,889				899,915		

Type of vessel.	Japan.				Russia.				Italy.				Austria-Hungary.			
	Built.		Building.		Built.		Building.		Built.		Building.		Built.		Building.	
	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).	No.	Tons.	No.	Tons (estimated).
Battleships (dreadnaught type) [1]	2	41,600	4	122,400	...	...	7	159,409	3	62,644	7	187,150	3	60,030	4	93,510
Battleships (predreadnaught) [2]	13	191,380	...	...	7	98,750	...	...	8	96,100	...	...	6	74,613	...	...
Coast-defense vessels [3]	2	9,086	...	...	2	10,380	...	...	...	...	...	...	6	41,700	...	...
Battle cruisers	2	55,000	2	55,000	...	...	4	128,000	...	...	...	...	...	...	...	...
Armored cruisers	13	138,483	...	...	6	63,500	...	...	9	74,020	...	...	2	13,380	...	...
Cruisers [5]	13	57,915	...	...	9	52,845	8	53,600	6	18,830	2	4,888	5	13,815	5	21,216
Torpedo-boat destroyers	50	20,487	2	1,676	91	36,748	44	53,664	36	16,807	15	14,203	18	9,450	...	...
Torpedo boats	27	3,017	...	...	14	2,132	...	...	68	11,584	2	272	39	6,852	24	5,886
Submarines	13	2,672	2	1,200	30	6,506	19	13,284	19	5,475	8	5,842	6	1,686	6	5,370
Total tons built and total tons building	...	519,640	...	180,276	...	270,861	...	407,957	...	285,460	...	212,355	...	221,526	...	125,982
Total tons built and building		699,916				678,818				497,815				347,508		

Warship Tonnage Table Notes.

[1] Battleships having a main battery of all big guns. (11 inches or more in caliber.)
[2] Battleships of (about) 10,000 or more tons displacement, whose main batteries are of more than one caliber.
[3] Includes smaller battleships and monitors.
[4] Armored cruisers having guns of largest caliber in main battery and capable of taking their place in line of battle with the battleships. They have an increase of speed at the expense of carrying fewer guns in main battery and a decrease in armor protection.
[5] All unarmored warships of more than 1,500 tons are classed as cruisers. Scouts are considered as cruisers in which battery and protection have been sacrificed to secure extreme speed. The word "protected" has been omitted, because all cruisers except the smallest and oldest now have protective decks.
[6] Does not include *Idaho* and *Mississippi*, recently sold, or ships of current program for which contracts have not been awarded
[7] Includes three submarines authorized in 1913; contract for fourth not yet awarded.

ACTIVE PERSONNEL.

Rank.	Eng. land.	Ger- many.	United States.	France.	Japan.	Russia.	Italy.	Austria- Hungary.
Admirals of the fleet	3	2	[1]1	...	2	...	...	...
Admirals	12	6	...	...	6	12	1	1
Vice admirals	22	12	...	15	19	20	10	2
Rear admirals	58	22	[2]25	30	38	21	19	15
Captains and commanders	702	154	212	360	270	346	137	80
Other line officers	2,508	2,220	1,680	1,419	1,965	1,378	753	558
Midshipmen at sea	639	448	...	77	119	...	73	175
Engineer officers	837	577	...	505	811	538	326	164
Medical officers	593	340	336	[3]390	[4]364	286	[3]259	84
Pay officers	750	276	231	211	388	...	228	[5]224
Naval constructors	122	162	75	187	[6]135	519	107	[7]141
Chaplains	147	30	24	...	...	85	...	11
Warrant officers	2,740	3,183	867	[8]147	1,569	...	1,340	387
Enlisted men	119,597	65,797	52,566	60,505	50,050	49,258	36,660	[9]17,689
Marine officers	465	[10]177	341	...	...	...	...	...
Enlisted men (marines)	* 21,414	[10]5,791	9,915	...	...	...	...	...
Total	150,609	79,197	66,273	63,846	55,736	52,463	39,913	19,531

Personnel Table Notes.

[1] The Admiral of the Navy.
[2] The United States now has, temporarily, as extra numbers, due to promotion for war service and to officers restricted by law to engineering duty only on shore only, 6 flag officers, 20 captains, 9 commanders, 6 lieutenant commanders and 1 lieutenant.
[3] Includes pharmacists.
[4] Includes pharmaceutical officers.
[5] Includes 21 officers of the Judge Advocate's Corps.
[6] Includes 50 ordnance and 10 hydrographic engineers.
[7] Includes 4 hydrographic engineers.
[8] Includes adjutants principaux; does not include premier maitres and maitres.
[9] Includes 4,000 recruits for 42 days.
[10] Marine infantry and seaman artillery.
* Includes 3,130 men of the Coast Guard.

NOTE.—In the table published Dec. 1, 1913, the number of captains and commanders given was 356 and other line officers 1,881. This apparent discrepancy was due to the inclusion of 213 Korvetten Kapitane (lieutenant commanders) with the captains and commanders. In the above table the Korvetten Kapitane (226) are included with the other line officers. Under Italy the number of vice admirals given was 18; this was a typographical error and should have been 8.

The following vessels are not included in the tables above:

Ships over twenty years old from date of launch, unless they have been reconstructed and re-armed within five years; torpedo craft over fifteen years old; those not actually begun or ordered, although authorized; transports, colliers, repair ships, torpedo depot ships, or other auxiliaries; vessels of less than 1,500 tons, except torpedo craft of less than fifty tons.

Vessels undergoing trials are considered as completed.

England has no continuing shipbuilding policy, but usually lays down each year four or five armored ships with a proportional number of smaller vessels.

Germany has a continuing shipbuilding program, governed by a fleet law authorized by the Reichstag. For 1913 there are authorized one battleship,

one battle cruiser, two cruisers, twelve destroyers. Eventual strength to consist of forty-one battleships, twenty armored cruisers, forty cruisers, 144 destroyers, seventy-two submarines.

Japan authorized $78,837,569 to be expended from 1911 to 1917 for the construction of war vessels.

Russian shipbuilding program provides for the completion by 1918 of four battle cruisers, eight small cruisers, thirty-six destroyers and eighteen submarines.—"Army and Navy Journal."

OBITUARY.

The death of Charles Ward on January 17, 1915, removed an engineer who had played a prominent part in marine engineering and whose efforts were always given to improvement and increase of efficiency. Mr. Ward was born in Seamington, England, March 5, 1841, and came to America in 1871. He had been trained as a gas engineer in England, and almost his first work in America was in Charleston, West Virginia, where he installed the first gas works and later became the superintendent and general Manager of the company. From this time Charleston became his home.

Outside of local prominence in western-river steamboating, Mr. Ward came into prominence before the engineers of the country when the late Admiral Melville invited the makers of water-tube boilers to compete for supplying the boilers for the coast defense vessel *Monterey*. Mr. Ward's boiler was tested in 1890, and four boilers of this type were installed in the *Monterey*, the first installation of water-tube boilers in a large war vessel.

Before this time smaller water-tube Ward boilers of different design had been used in steam launches of the United States Navy, and this type is being used at the present time.

Mr. Ward was also a pioneer in the use of screw propellers on western-river steamboats in the effort to reduce waste and increase efficiency as compared with the time-honored stern-wheel boats.

Mr. Ward was a man of agreeable personality who inspired confidence and respect in all who were associated with him. His business, which was at first carried out in his own name, later became The Charles Ward Engineering Works, which, since his serious illness some eight or ten years ago, has been carried on by his son, Mr. Charles E. Ward.

ASSOCIATION NOTES.

At a meeting of the Society held at the Navy Department December 30, 1914, the ballots cast for candidates for officers of the Society for the year 1915 were counted and the following declared elected:

President, Captain S. S. Robison, U. S. Navy.

Secretary-Treasurer, Lieutenant A. T. Church, U. S. Navy.

Members of Council: Captain B. C. Bryan, U. S. Navy; Engineer-in-Chief C. A. McAllister, U. S. C. G.; Commander U. T. Holmes, U. S. Navy.

Commander U. T. Holmes having been detached from duty in Washington, tendered his resignation as a member of the Council. Lieutenant Commander J. O. Richardson, U. S. N., was elected to fill the vacancy.

Lieutenant Commander H. C. Dinger, U. S. Navy, retiring Secretary-Treasurer, has rendered his financial statement in accordance with the By-Laws of the Society. The books were audited and found to be correct. On December 31, 1914, the total assets of the Society amounted to $10,167.50. There were no liabilities.

The numerical strength of the Society was as follows:

Members,	544
Associates,	331
Subscribers,	366
Exchanges,	73
Total,	1,314

The annual banquet of the Society was held at the Army and Navy Club in the City of Washington, D. C., on the evening of February 20, 1915. About 150 members and

guests were present, among whom were several members of both branches of Congress. The occasion was a most enjoyable one. Mr. H. L. Ferguson, of the Newport News Shipbuilding Company, acted as toastmaster and the following gentlemen responded to toasts:

Rear Admiral Bradley A. Fiske, U. S. Navy.

Senator CHARLES F. JOHNSON, of Maine.

Mr. WALTER M. MCFARLAND, of the Babcock & Wilcox Company.

Lieutenant Commander L. C. RICHARDSON, U. S. Navy.

The committee in charge was as follows:

Engineer-in-Chief C. A. MCALLISTER, U. S. C. G.

Lieutenant Commander H. C. DINGER, U. S. Navy.

Lieutenant Commander J. O. RICHARDSON, U. S. Navy.

Lieutenant A. T. CHURCH, U. S. Navy.

THE FOLLOWING MEMBERS AND ASSOCIATES have joined the Society since the publication of the last JOURNAL:

MEMBERS.

Babbitt, Herbert S., Lieutenant, U. S. Navy.
Baer, Joseph, Lieutenant, U. S. Navy.
Bassett, Prentiss P., Lieutenant, U. S. Navy.
Bradley, Willis W., Jr., Lieutenant, U. S. Navy.
Gayler, Ernest R., Civil Engineer, U. S. Navy.
Dixon, Virgil J., Lieutenant, U. S. Navy.
Hart, Thomas C., Lieutenant Commander, U. S. Navy.
Harvey, Urban, Lieutenant of Engineers, U. S. C. G.
Hill, Ellis Reed, 3d Lieutenant of Engineers, U. S. C. G.
Jennings, John C., Lieutenant, U. S. Navy.
Kingman, Howard F., Lieutenant, U. S. Navy.
Maxfield, Louis H., Lieutenant, U. S. Navy.
Owens, Charles T., Lieutenant Commander, U. S. Navy.
Peyton, Paul J., Lieutenant, U. S. Navy.
Prall, Whitney M., 2d Lieutenant of Engineers, U. S. C. G.
Smith, Harold T., Lieutenant, U. S. Navy.
Williams, Raleigh C., Lieutenant, U. S. Navy.

ASSOCIATES.

Broström, P. Daniel, Göteborg, Sweden.

Cornbrooks, Thomas M., Chief Engineer, Maryland Steel Company, Sparrows Point, Md.

Foord, James L., Chief Inspector, The Hartford Steam Boiler Inspection and Insurance Company, 800 Royal Insurance Building, Chicago, Ill.

Keller, O. B., care of Keuffel and Esser Co., 127 Fulton St., New York City.

Oatley, Henry B., Chief Engineer Locomotive Superheater Company, 30 Church St., New York City.

Rotter, Max, Chief Engineer, Busch-Sulzer Brothers Diesel Engine Co., St. Louis, Missouri.

Shipman, Frank J., The Texas Company, 17 Battery Place, New York City.